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THE BRAINTREE, MASSACHUSETTS, MUNICIPAL INCINERATOR

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U.S. ENVIRONMENTAL PROTECTION AGENCY

THE BRAINTREE, MASSACHUSETTS, MUNICIPAL INCINERATOR

This Processing and Disposal Division open-file report (SW-108)
was written by
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U.S. ENVIRONMENTAL PROTECTION AGENCY
1973

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PREFACE

Incineration is an important method of solid waste processing in the United States, and although 193 incinerators are in operation, little information on the performance of these units has been available. It is, therefore, not surprising that the effects of incineration on the environment are little understood and frequently ignored.

An incinerator discharges effluents into the environment in three states: solid, liquid, and gaseous. The sources of these effluents are the processes of combustion, gas cleaning, and residue quenching. Any determination of the pollution contribution to the environment by incineration must be concerned with all these effluents.

The Office of Solid Waste Management Programs has been conducting a testing program to characterize the performance of incinerators of different designs and configurations. The primary objectives of this program are to produce basic information that identifies the results of the incineration process and to develop reliable sample methodology.

During the studies it is considered necessary to make a complete analysis of all features that affect the operation of the facility as well as those that influence its potential for environmental pollution. The operation of the facility is not altered in any way unless specific study objectives dictate a change. Therefore, no special effort is

made to operate the facility at its design capacity; rather, it is tested at its "operating" capacity.

Reports from each study in this program are prepared primarily for use by the management of the facility, although they are available upon request to other interested technical personnel. Each report contains only the data obtained during one individual study. Data comparisons with other studies will not be made in individual study reports. Persons interested in receiving this report should contact the Office of Solid Waste Management Programs, Washington, D.C. 20460.

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INTRODUCTION

The original intent of this study was to obtain air pollution emissions data that would help the Office of Air Programs, U.S. Environmental Protection Agency, establish National Emission Standards for municipal incinerators processing greater than 50 tons per day in accordance with the Clean Air Act of 1970, as amended. In March, 1971, the Office of Solid Waste Management Programs (OSWMP) requested that the Town of Braintree allow it to test the facility for this purpose. However, OSWMP was not able to conduct any tests on the incinerator until July, 1972 because it had not been formally accepted by the town until September, 1971. By this time the National Emission Standards had already been established. Since the incinerator is a modern plant equipped with high-efficiency air pollution control equipment, data obtained from the tests can be used for possible substantiation of the standards.

An incinerator discharges effluents into the environment in the form of solids, liquids, and gases which are generated by combustion, gas cleaning, and residue quenching operations. Any determination of the pollution load imposed on the environment by an incinerator must investigate all these effluents. The prime objective of the Braintree study was to produce data that would measure these effluents and determine the incinerator's efficiency.

Because the incinerator processes a high portion of plastic wastes, another objective was to evaluate the effect this has on the operation of the facility particularly with respect to stack emissions.

SUMMARY

The Braintree Municipal Incinerator has two independent traveling grate furnaces of waterwall construction. Each furnace is designed to burn 120 tons/24 hour day of 5000 Btu/lb municipal solid waste. Both furnaces have electrostatic precipitators to control particulate emissions. Their steam generating boilers are designed to produce a total of 60,000 lb/hr steam at 250 psig.

Solid Waste

During the test period, 615 tons of solid waste having a density of 238 lb/cu yd were processed at an average rate of 28,000 lb/hr. The "as received" solid waste had 26.0 percent moisture and was 86.6 percent combustible and 13.4 percent noncombustible with an "as received" gross calorific value of 4,780 Btu/lb. The major combustible components were paper products, wood, plastics, rubber, and leather; the major noncombustible components were glass and metals.

The solid waste had an average of 73.7 percent of material that could be driven off upon heating and 26.3 percent ash on a dry basis.

Residue

With both furnaces operating, 5200 lb/hr of residue were discharged that had a wet density of 1555 lb/ cu yd, contained 2.1 percent unburned combustibles and 22.5 percent fines (dry basis), and had a gross calorific value of 179 Btu/lb. The material that could be driven off upon heating was 1.9 percent.

Floating residue from the quench trough had 26.3 percent unburned combustibles, 33.3 percent fines, and a gross calorific value of 2156 Btu/lb; 30.8 percent of it could be driven off upon heating.

Fly Ash

When both furnaces were operating, 120 lb/hr of fly ash having a density of 608 lb/cu yd and a gross calorific value of 3410 Btu/lb were discharged from the precipitators. Material that could be driven off upon heating amounted to 23.6 percent.

Grate Siftings

Each furnace discharged an average of 9.7 lb/hr of grate siftings containing 8.5 percent material that could be driven off upon heating and having a gross calorifc value of 820 Btu/lb.

Wastewater

With both furnaces operating, the quench trough discharged 84 gpm of 115 F wastewater to the sanitary sewer. The water had a pH of 8.5 to 9.9, suspended solids of 135 mg/l, and total solids of 606 mg/l.

Stack Emissions

The average carbon dioxide concentration in the stack gas was calculated at 9.0 percent and excess air was calculated to be 75 percent.

Particulate emissions averaged 0.15 gr/scf at 12 percent CO_2, 0.25 lb/1000 lb flue gas at 50 percent excess air, 35.5 lb/hr and

3.4 lb/ton of waste. There was no significant difference in the particulate emissions values when Armstrong Armorflex* was or was not processed.

Visible emissions (opacity) were higher when Armstrong Armorflex was burned than when it was not. During the total testing period, opacity was greater than or equal to 20 percent for 12.3 percent of the observed time of almost 20 hours. When Armorflex was burned visible emissions were greater than or equal to 20 percent opacity 18.3 percent of the time; while when Armorflex was not burned visible emissions were greater than or equal to 20 percent opacity 2.5 percent of the time.

The hydrogen chloride concentration in the stack was 487 ppm.

Steam Production

With both furnaces in operation, the boilers produced an average of 52,106 lb/hr of steam at 194 psig for an efficiency of 39 percent.

Plant Efficiency

In processing solid waste delivered to the incinerator; the weight of the solid waste was reduced by 79.7 percent; on a weight basis 99.2 percent of the material that could be driven off upon heating was, in fact, driven off; the volume of solid waste was reduced by 97.4 percent; and of the available gross calorific heat in the solid waste 99 percent was released.

* Armorflex is a plastic product produced by Armstrong Cork and Rubber Company.

CONCLUSIONS AND RECOMMENDATIONS

Even though the data collected during the study are only representative of the operation during the study period, it is the opinion of the OSWMP that the operation, waste quantities and characteristics, and test results are reasonably represenative of day-to-day operation of the facility (Table 1).

TABLE 1

SUMMARY OF TEST RESULTS

Item	As tested July 1972	As Designed	Difference (%)
Solid waste processed (lb/hr)	28,000	20,000	+ 40.0
Solid waste gross calorific value (Btu/lb)	4,780	5,000	- 4.4
Volume reduction (percent)	97	-	-
Weight reduction (percent)	79	-	-
Steam production (lb/hr-psig)	52,100-194	60,000-250	- 28.4*
Boiler efficiency (percent)	39	60	- 35.0
Excess air (percent)	75	50-100	-
Particulate emission (gr/scf @ 12% CO_2)			
With Armorflex	0.16	0.2	- 20.0
Without Armorflex	0.15	0.2	- 25.0
Visible emissions (minutes = 20%/test time			
With Armorflex	138.75/760	0	+ 18.3
Without Armorflex	10.75/435	0	+ 2.5

* Based on enthalpy comparison

The table shows that the facility was operated within its basic design limitations with respect to particulate emissions during the study period. Despite this fact, the particulate and visible emissions significantly exceeded the current Massachusetts General Laws which limit particulate emissions from existing municipal incinerators to 0.1 gr/scf at 12% CO_2 and visible emissions to less than 20% opacity at all times.

All of the residue, grate siftings, and fly ash from the operation are dumped uncovered on the land adjacent to the facility. The area is marshy, and rainwater runoff might carry these materials into the nearby Monatiquot River. Fly ash is transferred from the precipitator hoppers to the open dumpster tubs by continuously operating the rotary valves and using a water spray to reduce dusting. Despite the water spray, airborne material still exists and drainage from the tubs flows through a ditch to a pond adjacent to the river. In addition, residue quench water drains from the transfer truck into this pond. Frequent hosing of the area behind the incinerator also results in direct runoff to the pond.

An equipment maintenance program at the incinerator is practically non-existent. Repairs are made when something breaks down. Spare parts, facilities and equipment to perform repairs are not adequate for this sophisticated facility.

Housekeeping inside and adjacent to the building is done but not adequately. Safety devices and procedures are lacking throughout the facility, and there is a high incidence of public exposure to the hazard of falling into the pit when private vehicles deliver solid waste.

To achieve an environmentally acceptable operation and to relieve deficiencies in the areas of maintenance and safety, the

Office of Solid Waste Management Programs makes the following conclusions and recommendations:

1. Particulate and visible emissions must be lowered in accordance with State law. The Town of Braintree should retain a qualified consultant to evaluate the detailed technical and economic aspects of the problem and its various solutions. In considering potential solutions to the emission problem, five main factors can be adjusted to effect the lowering of particulate emissions:

(1) excess air-especially underfire air;

(2) Btu load (charging rate X heat content);

(3) steam producing capacity;

(4) particulate removal capability;

(5) operating schedules.

The interaction of all these factors is quite complex and the optimum solution potentially involves the adjustment of all five variables. The conceptually simplest solution and probably the most expensive would be to maintain all current operations and equipment except the precipitators which would have to be increased in efficiency. Another solution might be to reduce underfire air to reduce particulate entrainment in the effluent gases. This would, however, result in lowering throughput and steam production and increasing burning time. There are many other combinations, but the proper solution requires a balance of capital and operating monies.

Based upon the data collected in this study, it appears possible to continue processing Armorflex wastes. However, it will be necessary to manage the rate of processing of Armstrong wastes to limit the visible emission to less than 20 percent opacity at all times.

2. The practice of open dumping residue, grate siftings and fly ash must be stopped in favor of a sanitary landfill as required by the State Board of Health. The current site may not be acceptable because of its proximity to the Monatiquot River.

3. Modify the fly ash collection system to prevent the fly ash from becoming airborne.

4. Runoff water from the residue truck, operator hosings, and fly ash spraying should be directed into the sanitary sewer system.

5. Establish housekeeping and preventative maintenance programs that will improve the physical appearance and insure the reliability of the facility.

6. Implement the recommendations on safety practices, devices, and training programs contained in Appendix G.

7. Restrict or eliminate the delivery of solid waste by private citizens. If taken, this step will require a complete evaluation of the current collection system.

8. Check the physcial conditions of the boiler and precipitator metal parts that have possibly deteriorated due to secondary chemical reactions.

9. If the Town of Braintree does not deem it feasible to comply with these recommendations, the Town may have to shut down the incinerator due to regulatory or operational problems and seek another method of processing and/or disposing of the Town's solid waste load of more than 600 tons per week. The OSWMP continues to be willing, through its Major Technical Assistance Program, to aid the Town and any consultant it hires with technical guidance ranging from definition through implementation of corrective programs.

FACILITY DESCRIPTION AND OPERATION

General

The incinerator is located near the geographic center of the town, was completed in May, 1971, and serves a population of approximately 36,000 in the Town of Braintree. Operating funds for the incinerator are appropriated from the budget by the Town Finance Committee.

The facility is located at the old town disposal area, just west of the Southeast Expressway, and is oriented in a general northeast-southwest direction, with the refuse storage pit located on the southwest side of the building and the stack located on the northeast side (Figure 1).

The incinerator processes both industrial and residential wastes. Even though a collection firm, on a contract with the town, provides once a week residential waste collection, a significant amount of waste is delivered to the incinerator by town residents via private automobiles and small trucks. Industrial waste is transported to the incinerator by the industries themselves or by private collectors. Vehicles with capacities of 6,000 lb or more are charged from $3.00 to $20.00.

The design capacity of the incinerator is 240 tons per day based on solid waste having a heat content of 5,000 Btu per pound as fired. The plant has two identical but independent furnaces. The furnaces are charged by a P&H five-ton bridge crane with a 3 cu yd clam shell grapple bucket from a storage pit that is

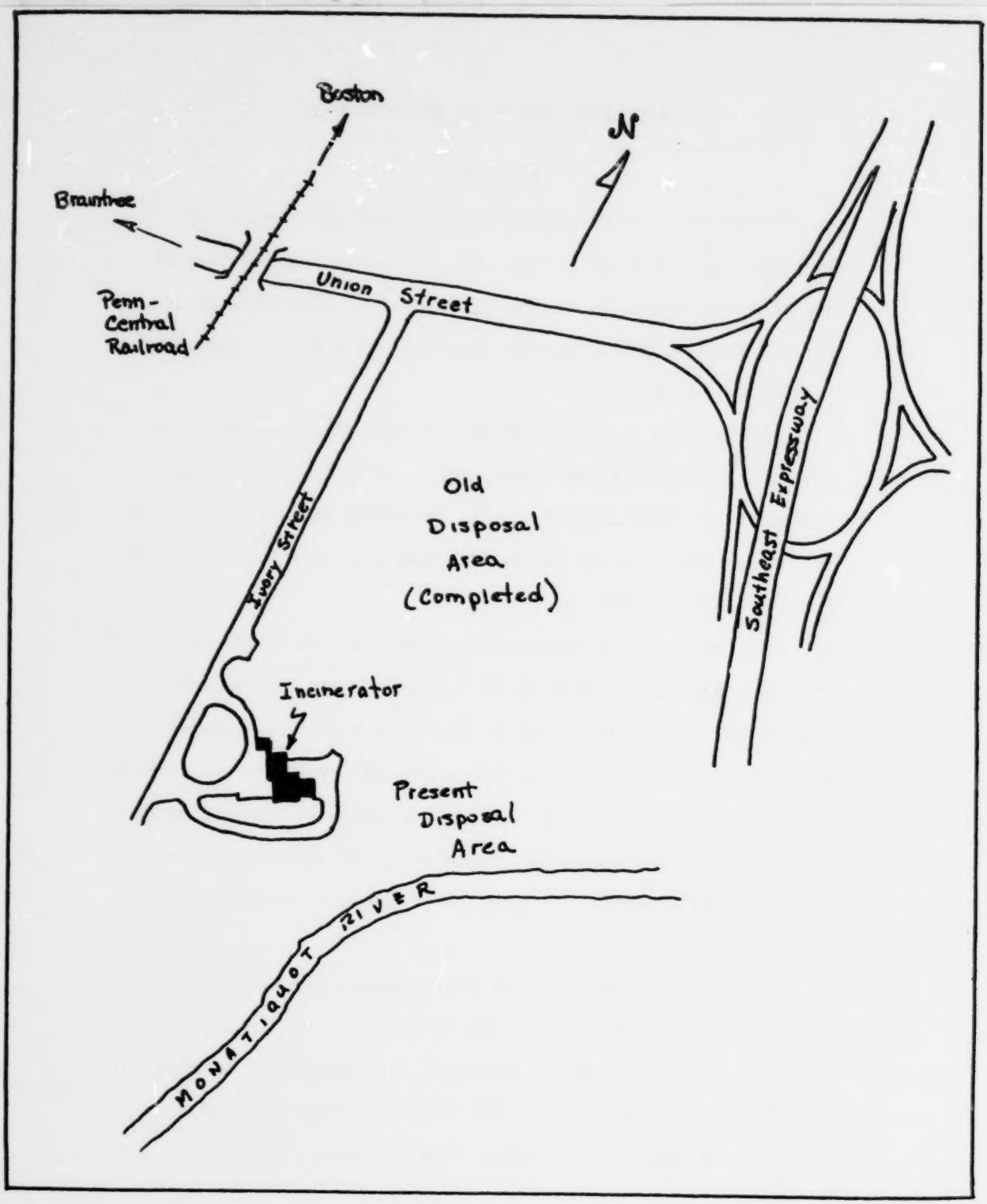

Figure 1. Incinerator and Surrounding Area.

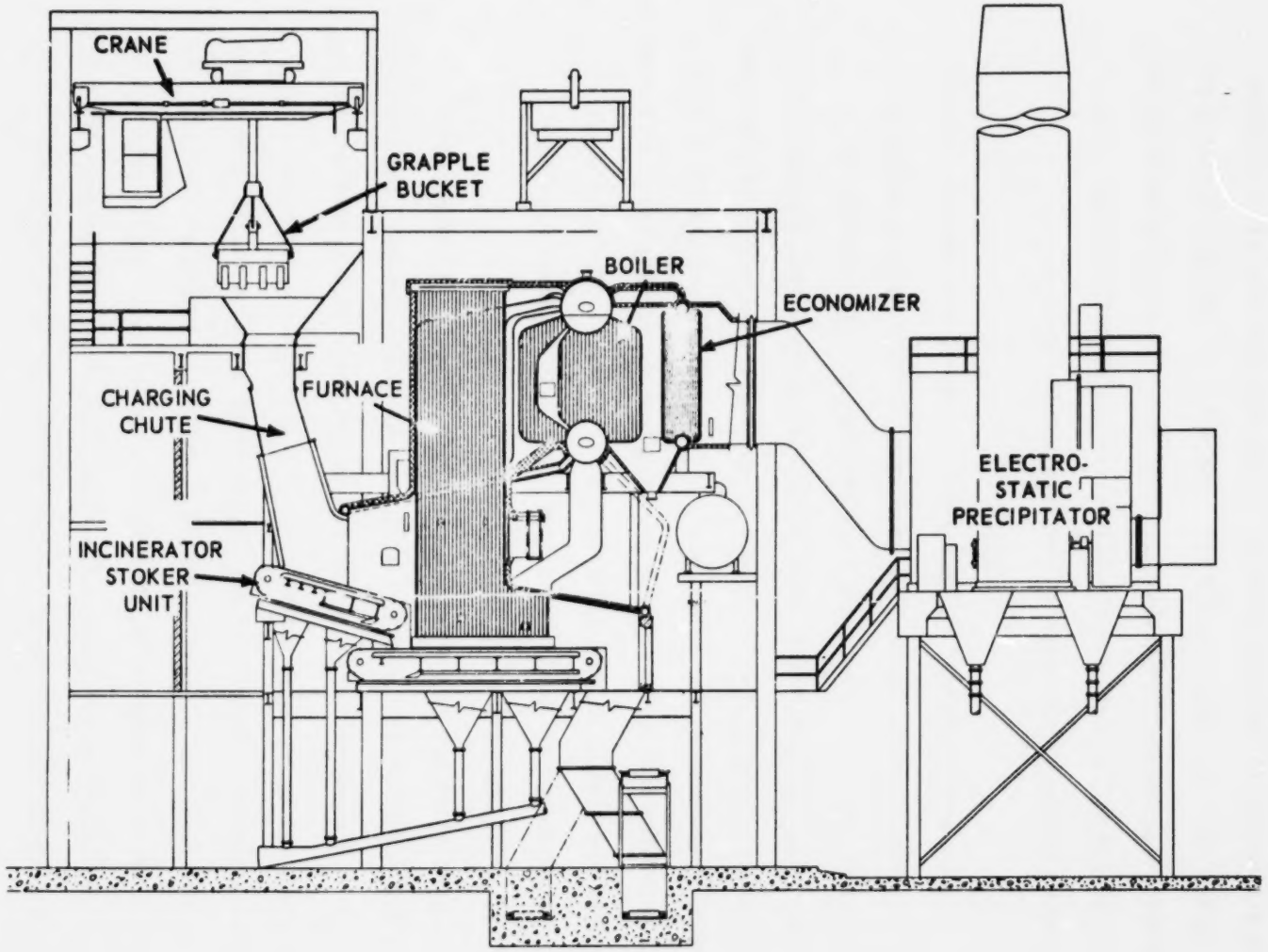

Figure 2. Cross Section of the Incinerator.

48 ft long, 28 ft wide, and 30 ft deep. The crane, bucket, and storage pit are housed in the main building, along with administrative offices, a locker room and shower facilities. The walls of the main building are non-bearing, precast prestressed concrete panels, while the walls of the furnace and boiler room are insulated, corrugated metal siding. The furnaces have a common stack and residue quench trough.

Furnaces

The two 120 tons per day water-wall furnaces, each having a volume of 2,780 cu ft, were constructed by Antonellis-Pyro Furnace Contractors, and are of the travelling grate type (Figure 2). Each furnace has a water-cooled charging chute attached to a charging hopper through which the refuse is fed by gravity onto a Riley Stoker Corporation 15° inclined drying grate that is 12 ft long and 7.5 ft wide. The refuse falls from it to a Riley horizontal burning grate that is 21 ft long and 7.5 ft wide. Each of the grates is equipped with a Riley hydraulic variable drive mechanism to permit regulation of the speed. The hydraulic systems of the drive mechanisms are water-cooled.

Combustion air is provided by separate Clarage Fan Company overfire air and forced draft (underfire air) fans for each furnace. The overfire air fan is rated at 9,000 scfm at 7.4 in. of water static pressure and can be regulated by an inlet damper control. The overfire air enters the furnace through slotted openings in the front and side walls; some of the openings have been plugged to permit better distribution of the air. The forced draft is rated at 18,000 scfm at 3 in. of water statis pressure and supplies underfire air through the rates from wind boxes beneath the grates. The drying section has two wind boxes on the rear half, while the

burning grate has four. The forced draft fan is also equipped with an inlet damper control. The air to the individual wind boxes is controlled by manually-operated dampers.

Residue Removal System

The residue from each furnace drops from the burning grate through a chute into a common residue quench trough filled with water. Siftings through the section of the drying grate beneath the charging chute drop directly into a hopper from which they fall through a duct into a container. Siftings through the remainder of the drying grate and the burning grate drop into the wind boxes, from which they are moved manually into hoppers. One hopper under the drying grate and two beneath the burning grate handle these siftings. These siftings also drop into containers through ducts from the hoppers. The grate siftings collected in the containers are manually transferred to the quench trough. A continuous flight conveyor drags the residue through the trough and up an inclined section for direct discharge into a waiting truck, which takes it to the adjacent disposal site.

Air Pollution Control Equipment

The gases leaving the economizer area of each unit pass through a 93% efficient Wheelabrator/Lurgi electrostatic precipitator designed to clean 32,000 acfm of dust-laden gases at 600°F. The gases flow horizontally through the 12.5 ft field length of the electrostatic precipitator at 3.38 ft/sec for a treatment time of 3.7 sec. The precipitator unit has a cross sectional area of 158 sq ft and a field height of 15 ft. Gas distribution through the precipitation zone is

by means of a 12 gauge perforated plate at the inlet.

The collecting surfaces of the electrostatic precipitator consist of cold-rolled, 18-gauge, carbon steel sections hanging in line from their supports to make up one wall of gas passage in the field. The pocketed sections are 18.75 in. wide and 15 ft high. There are 12 gas passages with a wall spacing of 10 in. The actual collecting area is 5,690 sq ft, while the projected collecting area is 4,740 sq ft. The high voltage system is made up of star-shaped 0.288 in. diameter wire discharge electrodes suspended vertically between the rows of collecting walls. The mild steel electrodes are 10 ft long and are held in alignment by 1-in. diameter pipe frames. The total length of the electrodes is 4,559 ft.

The power supply requirement for the precipitator unit is 480 volts, 60 Hertz, 3 phase. The 300-ma, 45 KV high voltage set consists of a liquid cooled transformer and silicon diode rectifier.

The rapping system includes 13 hammers with a single drive for the collecting surfaces and 12 hammers with a single drive for the discharge electrodes. Automatic timers control the duration of the rapping cycle and the interval between cycles.

An induced-draft fan rated at 39,600 cfm (@ 600 F) at 6 in. of water static pressure draws the gases through the furnace, boiler, and electrostatic precipitator on each unit for discharge through the stack. The stack is double-walled steel, 100 ft high with an inside diameter of 7 ft, and an outside diameter of 7.5 ft.

Fly Ash and Wastewater Handling

The fly ash from the electrostatic precipitator hoppers is discharged into portable containers which, when full, are removed by a rear-hoisting truck to the disposal area and emptied. A water spray is used to prevent dusting of the fly ash as it is dropped into the portable containers. Rotary feeders installed on each of the boiler-economizer hoppers were originally intended to remove fly ash collected there to the quench trough, but are not used because not enough is accumulated.

The water from the residue quench trough is discharged into the sanitary sewer system through two coarse screens that remove the larger solids.

Steam System

Each furnace is designed to produce 30,000 lb of steam per hour at 250 psig. The actual production is 26,000-28,000 lb/hr due to condenser capacity limitations. The convection section of each unit is a Riley RX-54/42 two-drum, single-pass water-tube boiler with a heating surface of 3,921 sq ft. The arches and all four walls of the furnaces are cooled by the water-tubes; those on the arches are refractory-clad. The tubes are 3.25 in. in nominal outside diameter. The projected surface area of the water-walls is 1,236 sq ft. The heating surface of the economizer is 1,506 sq ft.

A flow diagram of the steam system is shown in Figure 3. Boiler feedwater obtained from the town water system, after treatment in a water-softener, passes through the deaerator where it is heated to 240 F before it is pumped to the boilers. Two electrically driven boiler feed pumps and one steam-turbine driven pump supply the boilers

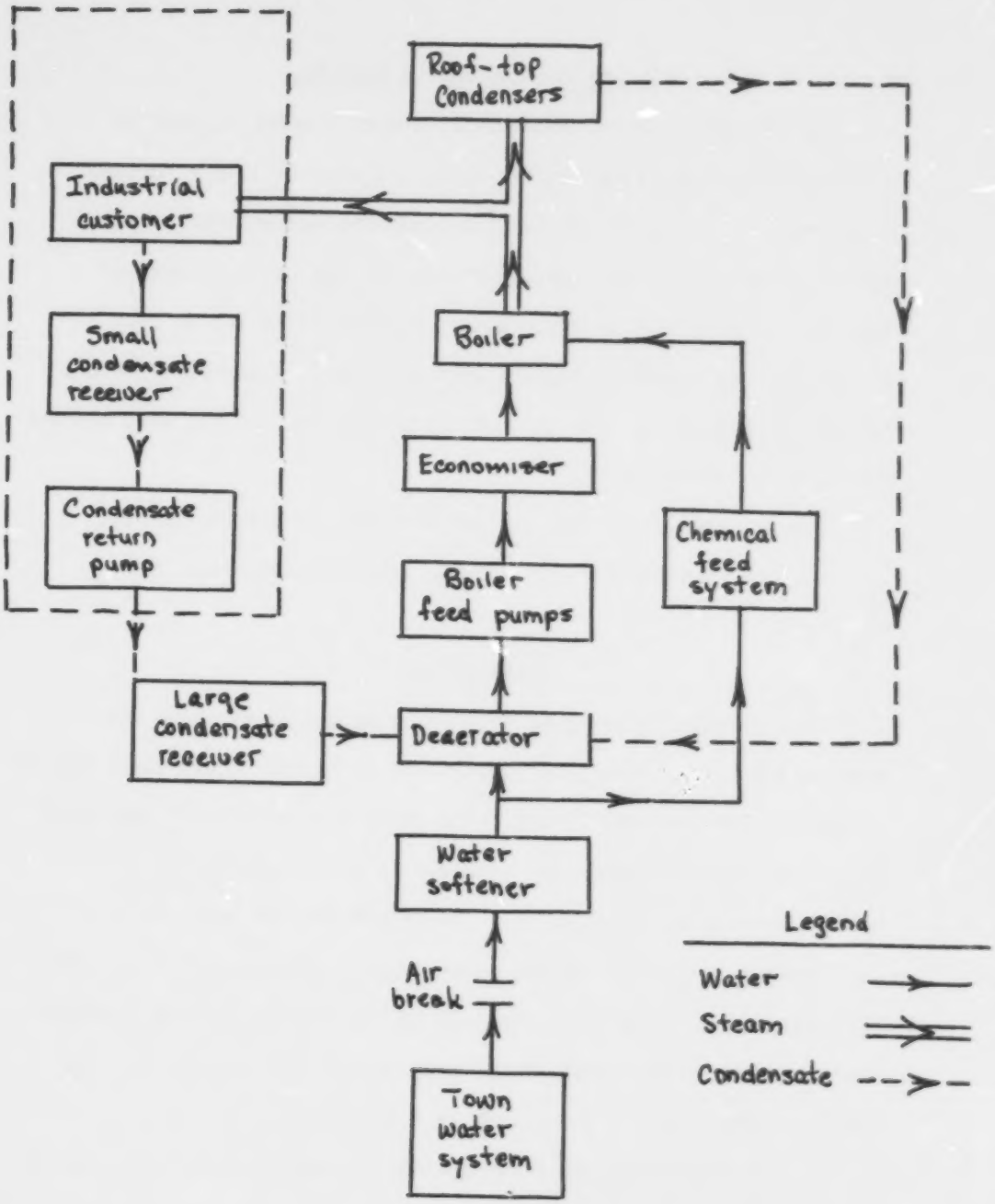

Figure 3. Steam System Flow Diagram.

with the required quantity of preheated and deaerated feedwater. Exhaust steam from the turbine is used in the deaerator heater.

A chemical feed system is included to introduce feedwater chemicals into the upper drums of the boilers and the deaerator. The lower steam drum and four lower water-wall headers have blowdown valves, and the water blown down enters a blowdown tank prior to discharge into the quench trough.

The two air-cooled condensers installed on the roof condense the steam for reuse. When the plant was constructed, provisions were made for delivery of the steam produced to a nearby industry for its use. However, the inability to negotiate a suitable contract with the company has curtailed the sale of steam in July, 1972. If the local industrial customer uses the steam, a spillover valve diverts the excess to the condensers. A small tank, which acts as a condensate receiver, and a condensate return pump are installed at the industrial location.

Each boiler is equipped with two Blaw-Knox T-30 Mark I-E retractable soot blowers for cleaning the outside of the boiler and economizer tubes. The steam lancing blowers have a traversing speed of 4 fpm and a rotating speed of 12 rpm.

A Riley Intertube Burner is installed in the rear wall of each furnace to augment the steam production from solid waste firing when required and to produce steam when solid waste is not fired. Each burner has a capacity of 34,000 cu ft/hr of gas and is capable of producing 30,000 lb/hr of steam. A fan supplies combustion air to the burner through a wind box.

Instrumentation

An upright instrument panel is located in front of the furnaces and contains gauges, indicators, and recorders for displaying the temperatures, pressures, component speeds and positions, etc. for each furnace. The following are indicated or recorded on the instrument panel: furnace outlet temperature and pressure; precipitator outlet temperature and pressure; pressure for overfire air fan outlet, stoker wind box, furnace and gas wind box; induced draft fan speed; steam drum level; pressure for the condensers, steam headers, boiler frums, main feedwater and dearerating heater. The panel also contains controls and indicators for drying grate speed, forced draft fan damper and overfire air damper, feedwater valve, and gas valve settings. Separate panels for the precipitators indicate the primary voltage and current, load current, and sparking rate.

The speeds of the grates are indicated on instruments located on the drive mechanisms. A panel on the dearator contains instruments which indicate the boiler feedwater temperature and related data. The gas pressure to the burners is indicated by pressure gauges on the backs of the burners.

Normal Operation

Industrial waste and that residential waste collected by the collector are received at the incinerator from 8:00 A.M. to 4:00 P.M. Monday through Friday, and from 8:00 A.M. to Noon on Saturday. Residential waste delivered to the incinerator by private vehicles (automobiles, small trucks, etc.) is accepted from 8:00 A.M. to 5:00 P.M. seven days per week. All of the larger trucks are weighed, while the private vehicles are not. The residue removed to the ultimate disposal

area is weighed during the first shift only; fly ash is not weighed.

The incinerator processes waste five days per week, Monday through Friday, during two eight hour shifts. Charging begins at 7:00 A.M., and light-off occurs when the solid waste drops onto the burning grate. The charging grate is closed about 10:00 P.M. for burndown.

At the time of the study, soot blowing of the units occurred once each shift (for about 30 sec, when steam pressure was low) when burning solid waste.

A sample of the water from each boiler was taken daily for chemical analysis to determine the blowdown required.

The engineer controls the incinerator's burning rate by adjusting the speeds of the drying grate and the overfire and underfire distribution. The drying grate speed can be adjusted remotely at the instrument panel, while the burning grate adjustment is made on the drive mechanism. The induced draft fan speed is controlled automatically to maintain a preset furnace draft.

The six regular workers on the first shift include an engineer, mechanic, crane operator, truck driver, laborer, and weigh clerk. Those on the second shift are engineer, mechanic, crane operator, truck driver, and laborer. The shift engineer is responsible for the plant operation in the absence of the superintendent.

Operation During Study

During the study period the incinerator was supposedly charged and operated in the same manner as on normal day-to-day operation, with two exceptions: (1) the fly ash truck was weighed on the scale before

dumping; (2) on Monday and Tuesday, July 24 and 25, the Armorflex plastic material normally delivered by a nearby industry was not delivered to the incinerator.

STUDY PROCEDURES

Samples

During the four day test period, the following samples were taken: (1) incoming solid waste; (2) residue; (3) grate siftings; (4) fly ash; (5) quench water; (6) furnace particulate emissions; (7) stack particulate emissions; and (8) stack HCl emissions. Visible stack emissions and control instrument data were also taken throughout the test period (Table 2 and Figure 4).

TABLE 2

SAMPLING SCHEDULE

Sample	Mon 24 July 1972	Tues 25 July 1972	Wed 26 July 1972	Thurs 27 July 1972
Solid waste	SW-1,-2*	SW-3*,-4	SW-5,-6*	SW-7*,-8
Residue**	R-1,-2	R-3	R-4,-5	R-6
Grate siftings**	none	GS-1,-2,-3, -4,-5	none	GS-6,-7
Fly ash**	FA-1,-2	FA-3,-4	FA-5	FA-6,-7
Quench water**	WW-1	WW-2	WW-3	WW-4
Furnace "A" gas	A-1	A-2,-3	none	none
Furnace "B"	B-1	B-2,-3	B-4,-5	none
Stack gas	C-1	C-2,-3	C-4,-5	C-6,-7

* Samples returned to laboratory for analysis.
** All samples returned to laboratory for analysis.

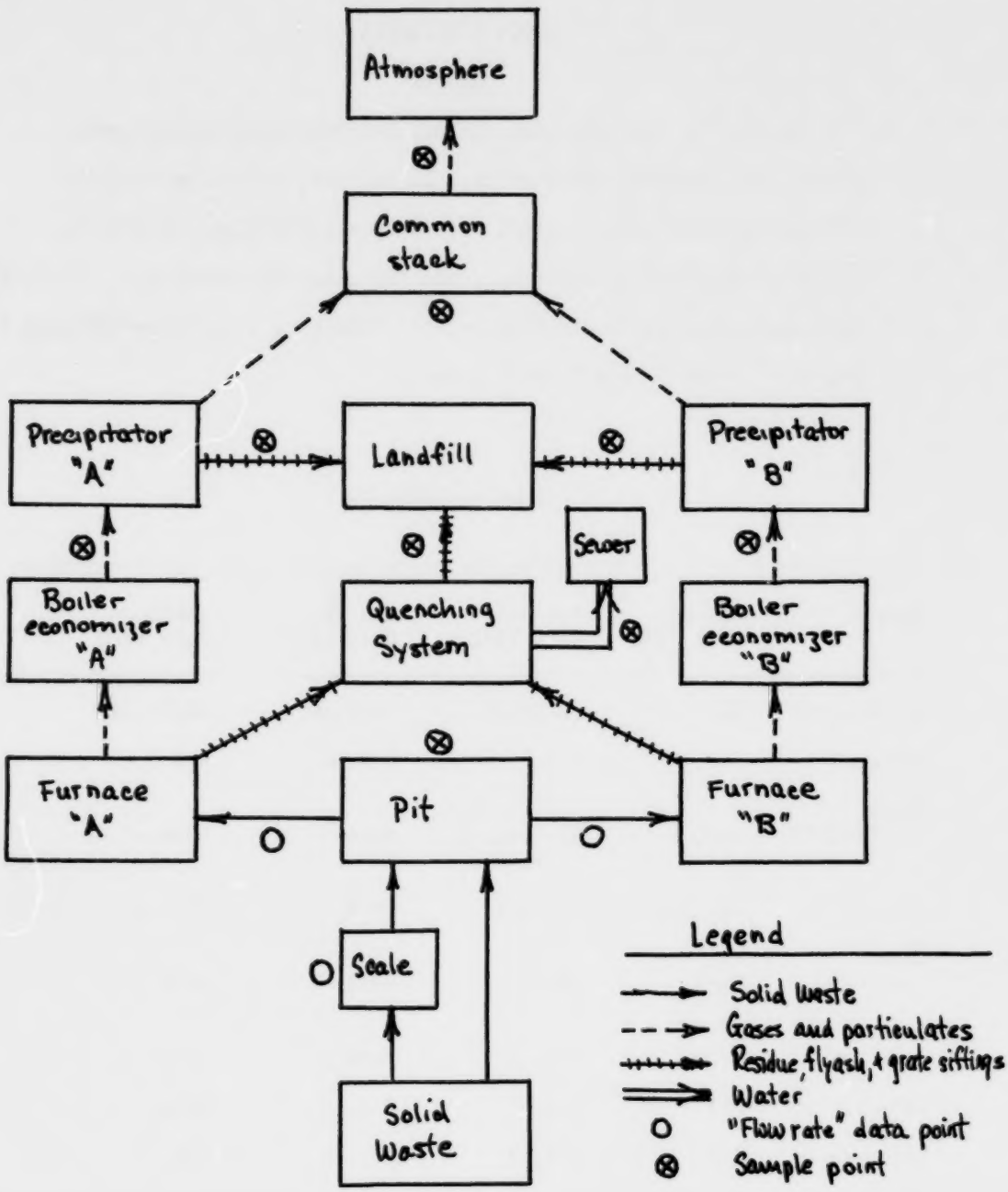

Figure 4. Sampling Location Diagram

Solid Waste

The charging rate for the two furnaces was determined by obtaining the average grapple-load weight and recording the number of grapple loads charged per furnace each hour. The average grapple-load weight was determined by placing a grapple-load of waste into a 3-cu yd (volumetrically calibrated) dump box four times per day and recording the weight.

To determine the solid waste composition two 100-225 lb samples were taken each day, separated in combustible and noncombustible categories made up of the eleven following components:

Combustibles:

(1) food waste
(2) garden waste
(3) paper products
(4) plastics, rubber, leather
(5) textiles
(6) wood
(7) fines
(8) smalls

Noncombustibles:

(9) metal
(10) glass and ceramics
(11) ash, dirt, rocks, ect.

After the larger, distinguishable items were separated, the smaller unidentifiable material remaining was sifted on a 1/8 in. mesh screen. Material passing through it comprised the "fines" components. The material remaining on the screen was sifted on a 1-in. mesh screen. Material passing

this screen was placed in the "smalls" component. The material remaining on the 1-in. mesh screen was separated and placed in the appropriate components. The material for each component was placed in 20-gal containers, weighed, and the net weight recorded on the appropriate forms.

From one of the two samples separated each test day a 15 lb representative sample, reconstituted from the separated components on a percent weight basis, was returned to the laboratory for analysis. Each of the reconstituted samples was placed in a tightly knotted plastic bag, and this bag was placed in a second plastic bag, which was also tightly knotted. Each sample was clearly identified by showing the plant, date, time, and sample number.

The four solid waste samples returned to the laboratory were subjected to moisture, proximate,[1,2] and ultimate analyses.[3,7]

To check on the density of the waste determined by the weights and volumes obtained with the dump box, two grapple-loads during the test were dumped on the floor of the separation area and density was determined by filling 20-gal containers to the top and weighing the contents until the volume and weight of the entire amount was determined.

Residue and Grate Siftings

At least one 5-gal sample of residue was taken each day and returned to the laboratory for moisture, composition, proximate, and ultimate analyses. Each sample was placed in a double plastic bag, clearly marked showing plant, time, sample number and type of sample. The samples were obtained by catching the residue in a perforated 5-gal bucket as it was discharged from the quench trough conveyor. The weight of the residue sample was determined by weighing the container after it had drained for several minutes and the density calculated. The weight of residue was determined by weighing the residue truck prior to dumping at the disposal area.

Grate siftings samples were taken twice - once while burning the Armorflex plastics and once when the Armorflex plastics were not burned. The weight and volume of the siftings were determined as they were removed. The samples were placed in double plastic bags and returned for moisture, proximate, and ultimate analyses.

A 5-gal floating residue sample was taken on the final day of the study and returned to the laboratory for composition, proximate, and ultimate analyses.

Fly Ash

One liter fly ash samples were obtained on each day from both precipitator hoppers. The samples were returned to the laboratory for moisture, proximate, and ultimate analyses.

The density of fly ash was calculated from the weight of a 5-gal container of fly ash.

The weight of fly ash was determined by weighing the dumpster rig prior to dumping at the disposal area.

Particulate and Gaseous Emissions

Stack sampling was performed in accordance with the procedures outlined in the "Federal Register, December 23, 1971, Standards of Performance for New Stationary Sources," and in "Specifications for Incinerator Testing at Federal Facilities" pertaining to the rear half of the particulate sampling train.

One integrated bag sample was collected at each sampling location during each particulate sampling run. The bags were analyzed by both an Orsat and automatic analytical instrumentation. Also, continuous sampling with the automatic analytical instrumentation for carbon dioxide, carbon monoxide, oxygen, and total gaseous hydrocarbons was conducted at the stack

sampling location during each particulate sampling run.

Separate samples for hydrogen chloride and particle size were collected at the stack sampling location on particulate sample Runs 5 and 6.

The schedule for sampling particulates and gases is shown in Table 3.

TABLE 3

GAS AND PARTICULATE SAMPLING SCHEDULE

DATE	Part. Sample Run	Stack			Precipitator A Inlet		Precipitator B Inlet	
		Part. Sample	Bag Sample	Automatic Gas Samp.	Part. Sample	Bag Sample	Part. Sample	Bag Sample
7/24	1	X	X	X	X	X	X	X
7/25	2	X	X	X	X	X	X	X
7/25	3	X	X	X	X	X	X	X
7/26	4	X	X	X			X	X
7/26	5	X	X				X	X
7/27	6	X	X	X				
7/27	7	X		X				

Instruments Monitoring

A record of the drafts, temperatures, grate controls, etc., was made during the stack tests at 20-min intervals and recorded. A record of operational adjustments was also maintained.

Visible Emissions

A record of the visible emissions was made during each stack test by a qualified smoke reader every 15 sec.

Liquid Samples

One quench water effluent sample was taken on each day of the study. A single grab sample of the city water was obtained. The liquid samples were placed in 1-liter containers. Temperature measurements were made at the time the samples were taken. Alkalinity and pH measurements[8] were made when the sample was taken to the cleanup area. The samples were clearly identified by showing the plant, date, time, sample number, and source. The samples were placed in a sample box for storage after chemicals had been added to preserve them during transit to the laboratory. Chemical analyses were performed on these samples[9] to determine: total suspended and dissolved solids and selected chemical constituents.

The flow rate of the quench water discharged during the study was measured to determine the amount of solids removed with it. The flow rate was determined by placing a 55 gal drum at the discharge pipe and recording the time needed to fill the drum.

RESULTS

Solid Waste Processed

During the four day study, the quantity and characteristics of the solid waste processed were determined to calculate plant efficiencies. Each of the two furnaces was operated at a capacity considered by the operator to be normal. Weigh station records and grapple load weights indicated that of 1.2 million lb of waste processed during the four days (Table 4), 0.6 million lb were residential wastes delivered by private collectors, 0.4 million lb were commercial and industrial wastes and 0.2 million lb were delivered by private cars and trucks. Separate data kept on high plastic content wastes delivered from the Armstrong Cork Company showed that approximately one-tenth of the total waste processed consisted of this special waste.

The plant processed an average of 28,000 lb of waste per hour. On a daily basis, the processing rate varied from 136 to 148 percent of the facility's rated capacity of 20,000 lb/hr.

Solid Waste Characteristics

The physical composition data (Table 5) and densities were calculated on an "as received" basis. The average density from two samples was 238 lb/cu yd as determined by means of the 20-gal garbage can method because the dump box scale was found to be out of calibration by an unidentifiable amount after the study was over. Since the average grapple load contained 7.43 cu yd, its average weight was 1770 lbs.

TABLE 4

SUMMARY OF SOLID WASTE PROCESSED

Date	Furnace	Number of Bucket Loads	Average Weight of Charge(lb)	Weight of Solid Waste(lb)	Time of Processing (hrs)	Average lb/hr	Rated Capacity lb/hr	Percent of Rated Capacity
7-24	A	111	1770	196,500	14.5	13,600	10,000	136
7-24	B	112	1770	198,200	14.5	13,700	10,000	137
7-24	A&B	223	1770	394,700	14.5	27,200	20,000	136
7-25	A	109	1770	192,900	14.5	13,300	10,000	133
7-25	B	114	1770	201,800	14.5	13,900	10,000	139
7-25	A&B	223	1770	394,700	14.5	27,200	20,000	136
7-26	A	---------- Furnace not run ----------						
7-26	B	86	1770	152,200	10.45	14,500	10,000	145
7-26	A&B	86	1770	152,200	10.45	14,500	20,000	73
7-27	A	80	1770	141,600	9.75	14,500	10,000	145
7-27	B	83	1770	147,000	9.75	15,100	10,000	151
7-27	A&B	163	1770	288,600	9.75	29,600	20,000	148
Totals During Entire Test Period		695	1770	1,230,200	49.2	28,000*	20,000	140*

*Run on 7-26 not included

TABLE 5

SOLID WASTE COMPOSITION

	24th Monday				25th Tuesday				26th Wednesday				27th Thursday				Average
	AM		PM*		AM*		PM		AM		PM*		AM*		PM		
	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)	%
Combustibles																	
Food Waste	6.1	3.8	2.7	1.9	13.5	9.2	4.7	3.5	1.1	0.5	4.5	4.2	4.2	3.2	5.9	2.6	3.6
Garden Waste	13.7	8.4	11.3	7.8	5.5	3.7	1.7	1.3	1.7	0.8	5.2	4.9	3.7	2.9	2.1	0.9	3.8
Paper Products	53.4	32.9	60.0	41.7	58.2	39.6	76.0	56.2	88.5	40.1	47.5	44.6	39.9	30.7	76.6	34.1	40.0
Plastic, Rubber, Leather	12.3	7.6	6.3	4.4	8.0	5.4	4.1	3.0	21.7	9.8	6.4	6.0	8.9	6.9	55.6	24.7	8.5
Textiles	0.7	0.4	4.7	3.3	1.9	1.3	0.3	0.2	3.1	1.4	1.7	1.6	0.1	0.1	0.1	0.1	1.1
Wood	24.9	15.4	15.6	10.8	2.7	1.8	21.4	15.8	20.3	9.2	7.3	6.8	46.5	35.8	31.6	14.1	13.7
Fines	9.4	5.8	11.2	7.8	6.5	4.4	3.0	2.2	18.6	8.4	5.8	5.4	3.0	2.3	17.9	8.0	5.5
Smalls	17.8	11.0	13.2	9.2	19.8	13.5	7.5	5.6	35.5	16.1	13.3	12.5	11.0	8.5	16.0	7.1	10.4
Sub Total	138.3	85.3	125.0	86.9	116.16	78.9	118.7	87.8	190.5	86.3	91.7	86.0	117.3	90.4	205.8	91.6	86.6
Noncombustibles																	
Metals	8.7	5.4	9.6	6.7	9.7	6.6	8.0	5.9	12.3	5.6	7.9	7.4	4.1	3.1	6.9	3.1	5.5
Glass and Ceramics	14.7	9.0	8.7	6.0	20.1	13.7	8.5	6.3	16.5	7.5	7.0	6.6	8.3	6.4	11.5	5.1	7.6
Ash, Dirt, Rock	0.5	0.3	0.7	0.4	1.1	0.8	0.0	0.0	1.3	0.6	0.0	0.0	0.1	0.1	0.5	0.2	0.3
Sub Total	73.9	14.7	19.0	13.1	30.9	21.1	16.5	12.2	30.1	13.7	14.9	14.0	12.5	9.6	18.0	8.4	13.4
Total Sample	162.2	100.0	144.0	100.0	147.0	100.0	135.2	100.0	220.6	100.0	106.6	100.0	129.8	100.0	224.7	100.0	100.0

*Representative sample returned to laboratory

The moisture content of the solid waste was obtained by drying a laboratory sample that was reconstituted on a weight percent basis. The proximate and ultimate analyses were performed on the dried combustible portion of this sample.

The results of the proximate analyses (Table 6) have been adjusted to the total solid waste sample. These calculations were based on the assumptions that the noncombustibles contain negligible calorific heat and matter that can be driven off upon heating. A sample calculation is in Appendix A.

TABLE 6

PROXIMATE ANALYSIS OF SOLID WASTE

Sample Date	As Received		Dry Basis	
	Moisture (%)	Gross Calorific Heat Content Value (Btu/lb)	Material Driven Off Upon Heating (%)	Ash (%)
SW-2 7/24/72	36.8	3810	73.1	26.9
SW-3 7/25/72	16.1	5640	73.2	26.8
SW-7 7/27/72	25.1	4900	74.8	25.2
Average	26.0	4780	73.7	26.3

Sample SW-6 on 7/26/72 was destroyed by fire during laboratory analysis.

The results of the ultimate analyses of the solid waste samples (Table 7) were adjusted to an "as received" basis by assuming that each sample contained only eight constituents (carbon, hydrogen, oxygen, nitrogen, sulfur, chlorine, inerts, and moisture).

TABLE 7

ULTIMATE ANALYSIS OF AS RECEIVED SOLID WASTE
(Percent)*

Sample	Carbon	Oxygen	Sulphur	Chlorine	Hydrogen	Nitrogen
SW-2	21.9	20.3	0.1	0.4	3.3	0.4
SW-3	29.0	20.5	0.3	1.5	3.9	0.2
SW-7	21.3	29.1	0.2	1.0	3.9	0.5

*Inert and moisture percentages omitted.
Sample SW-6 on 7-26-72 was destroyed by fire during laboratory analysis.

Residue

During the test period, residue was produced, at an approximate rate of 5,200 lb/hr. The average density of the moist residue from the residue conveyor was 1,555 lb/cu yd.

The residue samples were dried to remove quench trough water before the material was separated into metal, glass, fines, and unburned combustibles (Table 8).

The residue proximate analyses is shown in Table 9. The gross calorific value was determined by adjusting for the heat contained in the fines and unburned combustibles and assuming that there was no moisture in the residue or calorific heat in metals, rocks, or glass (see Appendix B).

TABLE 8

RESIDUE COMPOSITION (DRY BASIS)

Component	Sample R-1 7-24-72		Sample R-2 7-24-72		Sample R-3 7-25-72		Sample R-4 7-26-72		Sample R-5 7-26-72		Sample R-6 7-27-72		Average %	Floating Residue 7-28-72	
	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)	(lb)	(%)		(lb)	(%)
Metals	1.17	18.4	0.21	3.3	0.51	8.1	0.79	17.8	0.51	8.6	0.27	4.5	10.11	0.7	12.3
Rocks, ceramics glass, etc.	4.07	64.0	4.53	70.5	4.41	69.3	2.00	45.1	4.02	68.5	4.38	74.4	65.31	1.6	28.1
Fines	0.97	15.3	1.61	25.1	1.33	20.8	1.37	30.9	1.28	21.8	1.20	20.8	22.51	1.9	33.3
Unburned Combustibles	0.14	2.3	0.07	1.1	0.12	1.8	0.27	6.2	0.07	1.1	0.02	0.31	2.11	1.5	26.3
TOTAL	6.35	100.0	6.42	100.0	6.37	100.0	4.43	100.0	5.88	100.0	5.88	100.0	100.0	5.7	100.0

TABLE 9

PROXIMATE ANALYSIS OF RESIDUE (DRY BASIS)

Sample	Date	Gross Calorific Value (Btu/lb)	Material Driven Off Upon Heating (%)	Ash (%)
R-1	7-24	33	0.9	99.1
R-2	7-24	237	2.5	97.5
R-3	7-25	41	1.4	98.6
R-4	7-26	455	4.6	95.4
R-5	7-26	176	1.2	98.8
R-6	7-27	129	0.9	99.1
Average		179	1.9	98.1
Floating Residue	7-28	2156	30.8	69.2

The ultimate analyses data (Table 10) were obtained on the dry fines and unburned combustibles. The data were adjusted on a dry weight basis to 100 percent by assuming that each sample consisted of only seven constituents (carbon, oxygen, hydrogen, nitrogen, sulfur, chlorine, and inerts).

TABLE 10

ULTIMATE ANALYSIS OF RESIDUE (Dry Basis)
(Percent)*

Sample	Carbon	Oxygen	Hydrogen	Nitrogen	Sulfur	Chlorine
R-1	0.6	0.2	0.04	0.02	.04	0.0
R-2	1.8	0.3	0.15	0.05	0.2	0.0
R-3	0.6	0.5	0.07	0.03	0.2	0.0
R-4	3.8	0.2	0.2	0.1	0.1	0.0
R-5	1.1	0.03	0.03	0.01	0.03	0.0
R-6	0.5	0.0	0.07	0.03	0.3	0.0
Average	1.4	0.21	0.09	0.04	0.15	0.0
Floating Residue	21.6	4.8	2.3	0.6	0.4	1.0

*Inert percentage omitted.

Samples of the residue floating on the quench trough were dried and separated into the same categories (i.e. glass, fines, etc.), and subjected to proximate and ultimate analyses. These results appear with the regular residue results.

Fly Ash

The amount of fly ash produced during the study period was determined by weighing the fly ash collection boxes. Some error is inherent in the measurements, due to the use of a water spray to prevent fly ash becoming airborne which carried a small quantity of the ash to the drainage ditch. Approximately 120 lb/hr of fly ash

were produced based on weighing the fly ash containers prior to dumping in the landfill. The average wet density from daily samples was 608 lb/cu yd.

The proximate analyses of the dried fly ash samples are shown in Table 11. The results of the ultimate analyses are displayed in Table 12. These data were adjusted on a dry weight basis to 100 percent by assuming that each sample consisted of seven constituents (carbon, oxygen, hydrogen, nitrogen, sulfur, chlorine, and inerts). The values for carbon and chlorine percents on Sample FA-2 seem out of line compared to the other samples, cannot be explained, but represent precise analysis.

TABLE 11

PROXIMATE ANALYSIS OF FLY ASH (Dry Basis)

Date	Sample	Gross Calorific Value (Btu/lb)	Material Driven Off Upon Heating (%)	Ash (%)
7-24-72	FA-1	5010	20.5	79.5
7-24-72	FA-2	3500	27.5	72.5
7-25-72	FA-3	3500	22.3	77.7
7-25-72	FA-4	6310	32.1	67.9
7-26-72*	FA-5	2450	24.8	75.2
7-27-72	FA-6	1500	19.8	80.2
7-27-72	FA-7	1620	18.0	82.0
Average		3410		

*Only furnace B operating

TABLE 12

ULTIMATE ANALYSIS OF FLY ASH (Dry Basis)
(Percent)*

Date	Sample	Carbon	Oxygen	Hydrogen	Nitrogen	Sulfur	Chlorine
7-24-72	FA-1	17.00	.00	0.40	0.24	0.51	2.35
7-24-72	FA-2	6.22	1.10	0.39	0.10	2.48	17.20
7-25-72	FA-3	16.30	2.09	0.40	0.40	0.51	2.60
7-25-72	FA-4	27.60	1.80	0.58	0.56	0.56	0.90
7-26-72	FA-5	18.60	2.39	0.53	0.29	0.49	2.50
7-27-72	FA-6	13.30	1.55	0.28	0.22	0.85	3.60
7-27-72	FA-7	8.52	2.02	0.45	0.16	0.85	6.00
	Average	15.36	1.56	0.43	0.28	0.89	5.02

* Inert percentages omitted.

Grate Siftings

During the study period, 9.7 pounds of grate siftings were produced per hour by each furnace. The samples of grate siftings were assumed to be dry only picking up moisture during sampling or in transit.

The results of the proximate analyses or the samples of grate sifting fines appear in Table 13, and the results of the ultimate analysis are in Table 14. The grate siftings fines were assumed to have the same seven constituents as the residue and were adjusted to 100 percent accordingly.

Tap and Wastewater

The volumetric flowrate of the quench trough effluent was measured with one and two furnaces operating. One furnace produced 44 gpm effluent water and two furnaces produced 104 gpm. The temperature at either flowrate was approximately 115 F.

Data on tapwater and wastewater characteristics as samples at the exit of the quench trough are presented in Table 15.

TABLE 13

PROXIMATE ANALYSIS OF GRATE SIFTINGS FINES (Dry Basis)

Date	Sample	Furnace	Windbox	Gross Calorific Value (Btu/lb)	Material Driven Off Upon Heating (%)	Ash (%)
7-25	GS-1	B	1 and 2	452	5.7	94.3
7-25	GS-2	A	1 and 2	1140	14.1	85.9
7-25	GS-3	B	5 and 6	627	6.1	93.9
7-25	GS-4	A	3 and 4	785	8.6	91.4
7-27	GS-5	A	5 and 6	653	5.1	94.9
7-27	GS-6	A	3 and 4	732	7.5	92.5
7-27	GS-7	B	3 and 4	1370	12.2	87.8
Average				820	8.5	91.5

TABLE 14

ULTIMATE ANALYSIS OF GRATE SIFTINGS FINES (Dry Basis)
(Percent)*

Date	Sample	Furnace	Carbon	Oxygen	Hydrogen	Nitrogen	Sulfur	Chlorine
7-25-72	GS-1	B	4.00	0.00	0.19	0.17	0.49	0.59
7-25-72	GS-2	A	8.34	2.74	0.57	0.34	0.75	0.64
7-25-72	GS-3	B	4.19	0.00	0.37	0.20	0.40	0.62
7-25-72	GS-4	A	4.90	0.90	0.49	0.20	0.75	1.05
7-27-72	GS-5	A	3.72	0.00	0.30	0.17	0.30	0.41
7-27-72	GS-6	A	4.60	0.50	0.43	0.00	0.60	0.98
7-27-72	GS-7	B	8.96	0.00	0.75	0.17	0.49	0.50
Average			5.53	0.59	0.44	0.18	0.54	0.68

*Inert percentages omitted

Table 15

CHEMICAL CHARACTERISTIC OF TAPWATER AND WASTEWATER*

Parameter**	Wastewater				Average	Tapwater
	7/24	7/25	7/26	7/27		7/24
pH	9.9	8.5	9.5	9.0	8.5-9.9	7.5
Acidity ($CaCO_3$pH 8.3)	0	0	0	0	0	0
Alkalinity ($CaCO_3$ pH 4.5)	82	131	78	66	89	24
Chlorides	165	116	181	98	140	62
Total Hardness ($CaCO_3$)	158	134	186	84	141	42
Sulfate	126	78	60	60	81	18
Phosphate, total (P)	0.98	0.99	0.56	1.61	104	0.16
Iron	1.29	0.84	1.08	2.60	1.45	0.05
Magnesium	1.0	1.0	0	2.0	1.0	3.0
Lead	0.3	0.3	0.2	0.4	0.3	0.0
Zinc	1.73	0.98	1.62	1.81	1.54	0.27
COD	102	105	22	50	70	11
Total Solids	705	596	669	452	606	179
Dissolved Solids	580	439	582	282	471	175
Suspended Solids	125	157	87	170	135	4
Nitrite Nitrogen	0.85	1.13	0.24	0.09	0.58	0.00
Nitrates Nitrogen	0.2	0.3	0.4	0.5	0.35	0.3
Ammonia Nitrogen	2.0	4.4	1.4	0.0	2.0	00
Color	30	60	20	25	34	8
Calcium	62	52	72	30	54	12

* Water used for residue quenching only

** Expressed as mg/l except pH and color.

Monatiquot River

To determine if the incinerator operation was affecting the adjacent Monatiquot River, water samples were taken upstream and downstream from the plant, in the plant drainage ditch, and in the river opposite the drainage ditch terminus (Figure 5). The analysis of the four samples is presented in Table 16.

The following is excerpted from a report by Leonard W. Lion of OSWMP's Special Projects Section:

> "The Braintree Incinerator and the entire surrounding area is predominantly marsh land. Many pools of standing water can be seen in the vicinity of the plant. Since residue and fly ash disposal are carried out at the plant site, the disposal areas are marshy in nature and obviously must periodically come in contact with the local ground water.
>
> The plant's old (finished) disposal area is located to the north of the facility and has received earth cover. This area is bounded on the east by the Southeast Expressway. Separating the expressway and the finished fill is a small creek bed. The waters flowing through this creek are tributary to the Monatiquot and are obviously polluted. An oil film is readily apparent in the creek and possibly originates from several upstream filling stations. All runoff waters from the finished Braintree landfill area would be channeled into this small creek and subsequently the Monatiquot River.
>
> The more recent residue and ash disposal area of the plant lies to the south, is uncovered, and is approximately 200 to 300 feet from the banks of the Monatiquot. Prior to our arrival at the site, a drainage ditch had been cut through the residue diposits to allow water to escape from the back of the plant. The back of the plant is virtually encircled by berms from residue fill operations, and all rainwater or spills into this area must leave via the drainage ditch. The ditch is cut in such a way that waters travel through residue deposits and then pond roughly 200 feet from the river bank. Infiltration of these waters into the Monatiquot will be the eventual consequence of this practice.
>
> The drainage water situation is worsened by the practice of plant operators who periodically hose off the area behind the plant, directing large quantities of ash-laden water into the ditch. Additional problems are added by the use of open bins to catch the fly

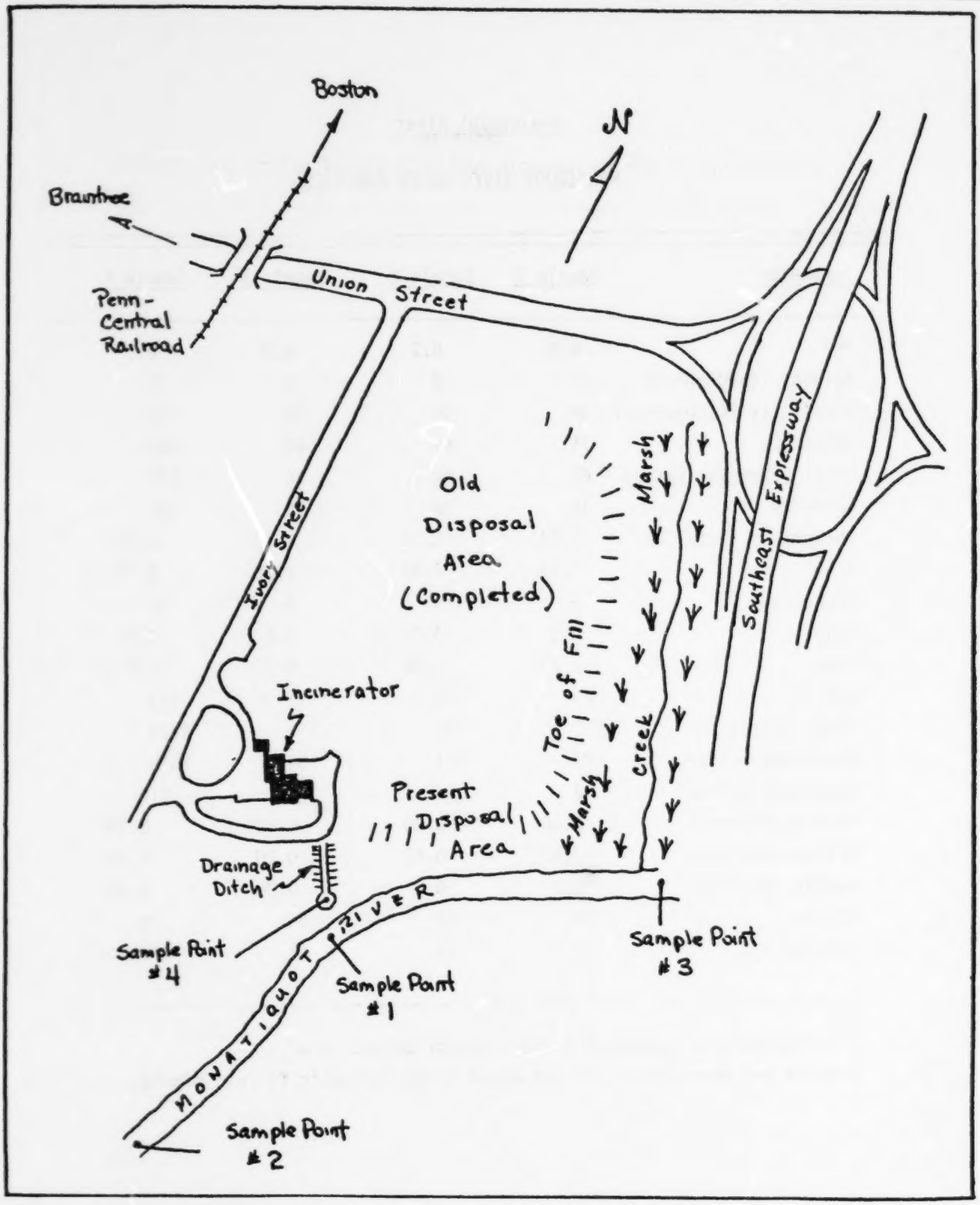

Figure 5. Monatiquot River Water Sample Diagram.

TABLE 16

MONTIQUOT RIVER WATER ANALYSES

Parameter	Sample 1	Sample 2	Sample 3	Sample 4
*pH	6.8	6.7	6.8	6.5
Acidity ($CaCO_3$pH8.3)	11	8	8	19
Alkalinity ($CaCO_3$pH4.5)	36	55	35	83
Chlorides	75	69	68	843
Total Hardness ($CaCO_3$)	62	52	56	647
Sulfates	15	18	15	306
Phosphates (Total P)	0.04	0.11	0.18	0.31
Iron	1.92	1.49	1.68	3.50
Magnesium	5	3	4	10
Lead	0.0	0.0	0.0	1.4
Zinc	0.26	0.06	0.17	41.8
COD	25	24	23	213
Total Solids	227	184	197	2734
Dissolved Solids	225	181	194	2516
Suspended Solids	2	3	3	218
Nitrite Nitrogen	0.00	0.00	0.00	0.19
Nitrate Nitrogen	0.50	0.40	0.20	0.10
Ammonia Nitrogen	0.0	0.0	0.00	0.80
*Color	75	80	80	10
Calcium	17	15	15	243

*Parameters expressed in Mg/l except pH and color

Flow of the Montiquot River estimated to be 1.0 cubic ft. per minute.

ash from the incinerator's electrostatic precipitators. The open bins allow wind to swirl and carry fly ash out and to subsequently be deposited behind the plant (the same area later to be hosed off). As an apparent preventative to wind blowing, water was applied to one bin. This resulted in drainage from the bottom of the bin and of course, fly ash was carried out with the drain waters.

Since all apparent drainage from the site's disposal area, including the ditch water, percolates through the ground before reaching the river, it is more likely that no positive identification of pollution will be made. Making the identification task more difficult is the fact that the Monatiquot is heavily polluted before it even reaches the Braintree site. Apparently, upstream discharges by industry have eliminated all life in the river. The growth of algae was not even observed; the shallow river bottom was instead coated with an orange deposit pointing to the possibility of high iron concentrations."

No firm conclusions can be drawn from the single grab samplesas to whether site runoff waters affect the Monatiquot River because they do not flow directly to the River but are filtered as they percolate through the ground. It is, however, obvious that the drainage ditch water (Table 16, Sample 4) is of significantly poorer quality than water already in the stream. The practice of draining wastewaters from the incinerator site to the disposal area should be discontinued.

Analysis of the samples taken upstream and downstream of the incinerator site (Samples 2 and 3) indicates that the River is contaminated to essentially the same degree at each location. Although there is an increase in phosphates, iron, and zinc between these two locations, there is a decrease in alkalinity, sulfates, and nitrates nitrogen.

Particulate Emissions

During the stack tests, Orsat and automatic instrumentation analyses were run on stack gases to determine their composition, but data were discarded as inaccurate because they totally conflicted with flow measurements in the stack and mass balance calculations. From the ultimate analyses of

solid waste samples returned to the laboratory the theoretical gases of combustion were determined for three samples and compared with actual stack flows to determine the percent carbon dioxide and excess air value. A sample calculation is shown in Appendix C. The average values of computed excess air and CO_2 concentration are used for the three runs for which no solid waste ultimate analyses were available.

The stack test results are presented in Table 17. The particulate emission loading results are presented for the weight of particulate picked up in the front half of the EPA sampling train. If particulate loading from the total train was used, the average emissions in Table 17 would be increased about 17 percent.

Particulate data on the precipitator inlets were not considered valid due to high indicated mass flows not possible in the furnace and also to inadvertent immersion of the probes into piles of particulate lying in the duct during the test runs.

TABLE 17

STACK TESTING SUMMARY

Test Run Number	Calculated CO_2 content in stack gas (%)	Stack gas temperature(°F)	Calculated excess air(%)	Stack gas Flow SCFM	Stack gas Flow ACFM	Particulate Emissions gr/scf @12% CO_2	Particulate Emissions lb/1000 lb stack gases @50% E.A.	Particulate Emissions lb/hr	Particulate Emissions lb/ton waste
C-1	8.3	487	84	38,200	68,200	0.25	0.40	56.8	4.5
C-2	10.1	527	53	41,900	78,000	0.10	0.17	31.0	3.1
C-3	9.0*	518	75*	40,700	75,100	0.09	0.14	24.4	1.9
C-4 **	Run was not isokinetic		—	—	—	—	—	—	—
C-5 **	9.0*	429	75*	26,500	44,500	0.19	0.31	31.7	5.0
C-6 **	8.7	488	87	38,800	69,400	0.18	0.32	44.2	3.5
C-7 **	9.0*	512	75*	40,000	73,300	0.10	0.16	24.9	2.2
Average	9.0	494	75	37,700	68,100	0.15	0.25	35.5	3.4

*Average of runs C-1,-2,and-6.
** Burning Armorflex

Visible Emissions

During each stack test run, opacity readings were made by a qualified smoke reader supplied by the State of Massachusetts. A summary of the data is shown in Table 18. Note that on Runs C1-C3 the visible emissions were equal to or greater than 20 percent opacity of 10.75 of 455 minutes (2.5%) while on runs C4-C7 they were equal to or greater than 20 percent opacity for 138.75 of 760 minutes (18.3 percent). This trend apparently correlates to the fact that Armstrong Armorflex was not processed on Runs C1-C3 and was burned on Runs C4-C7. Table 19 shows a summary of Armstrong deliveries at the scale house and processed waste on a day-by-day basis.

The high peaks in opacity readings were compared to precipitator hammer cycling and no correlation was found.

Effects of Burning Armorflex

Ultimate and proximate analyses show that Armorflex contains 59.2 percent carbon and 14.3 percent chlorine as major components and that it has a gross calorific value of 10,897 Btu/lb. Comparison of characteristic data on solid waste and solids discharged from the facility on days when Armorflex was and was not burned reveals no significant trends. Unfortunately, the particulate sizing tests failed and because of sampling equipment problems no HCl concentration in stack gas was determined on days when Armorflex was not burned. The particulate loading also showed no significant change when Armorflex was burned (Table 17), but visible emissions increased markedly when it was (Table 18 and 19).

TABLE 18

VISIBLE EMISSIONS

Date	Time	Test Run No.	Elapsed Time(Min)	Opacity High	Opacity Low	Average Opacity(%)	Time equal to or greater than 20% Opacity Minutes	Time equal to or greater than 20% Opacity %
7-24-72	1700-1900	C-1	120	25	0	7.1	6.0	5.0
7-25-72	1000-1200	C-2	120	20	0	2.5	0.75	0.6
7-25-72	1445-1800	C-3	195	80	0	5.2	4.0	2.0
7-26-72*	955-1300	C-4	185	90	0	15.0	73.5	39.7
7-26-72*	1400-1730	C-5	210	60	0	10.0	39.0	18.5
7-27-72*	930-1225	C-6	175	40	0	10.0	13.0	7.4
7-27-72*	1400-1710	C-7	190	50	0	15.0	13.25	6.9

*Burning Armorflex

TABLE 19

ARMSTRONG WASTE DELIVERIES

Date	Test Run No.	Material charged during day (lb)	Armstrong waste Delivered (lb)	Armstrong waste % of solid waste for day
7-24-72	C-1	394,700	20,460*	5.2
7-25-72	C-2,-3	394,700	23,080*	5.9
7-26-72	C-4,-5	152,200	39,530	26.0
7-27-72	C-6,-7	288,600	33,400	11.6

*Regular Armstrong trash - Armorflex excluded

Special Emissions

HCl concentration measurements were made on the stack gas and the average concentration was 487 ppm (Table 20). Because of sampling equipment problems, measurements were taken only when Armorflex was being burned.

Stack gas particle size measurements were made, but the test results were inconclusive.

A water condenser on the gas stream prior to the automatic instruments collected a thick, dark sample of condensed material, which was analyzed for chemical composition (Table 21). The iron, chromium, manganese, nickel, and copper detected probably did not come from the incineration of the solid waste, but from some secondary reaction in the furnaces, boilers, precipitators, or stack.

TABLE 20

HYDROGEN CHLORIDE CONCENTRATIONS IN STACK GAS

Test Run Number	Date	Volume of Gas (ft^3)	MG of HCl	ppm HCl
C - 4	7/26	5.977	149.7	586
C - 5	7/26	5.868	63.2	252
C - 6	7/27	5.800	107.8	435
C - 7	7/27	5.851	168.3	673
Average		5.874	122.7	487

TABLE 21

ANALYSIS OF CONDENSATE COLLECTED IN THE MOISTURE TRAP OF THE AUTOMATIC INSTRUMENTATION

Parameter	Mg/l
Total solids	20,000
Total sulfur	6,300
Iron	2,200
Lead	100
Zinc	580
Aluminum	620
Chromium	780
Manganese	62
Nickel	360
Copper	139
Chlorides	8,200

Steam Production

Steam production is summarized in Table 22. System makeup water is approximately 5 percent because of blowdown and losses in the closed system. The preheater (economizer) heats the feedwater to 240 F, and average steam production was 52,106 lb/hr at 194 psig for an efficiency of 39 percent (see Appendix E).

TABLE 22

STEAM GENERATION

Date	Boiler A (lb/hr)	Boiler B (lb/hr)	Total Rate (lb/hr)	Heater Pressure (psig)
7/24	25,680	28,237	53,917	202
7/25	26,676	25,176	51,852	192
7/26*	-	29,222	-	201
7/27	26,000	24,550	50,550	190
Average	26,119	25,988	52,106	194

*Not included in average because only one furnace operating

Heat Balance

Of the total average heat released in the incinerator of 132,500,000 Btu/hr, only 105,586,235 Btu/hr can be accounted for by boiler operation, radiation, and sensible heat content of the solids and gases leaving the facility (See Appendix F).

Plant Efficiencies

The plant efficiencies for weight and volume reduction, material driven off upon heating, and heat release are shown in Table 23. The calculations are shown in Appendix D are based on average values for the testing period.

TABLE 23

PLANT EFFICIENCY

Item	Efficiency (Percent)
Weight reduction	78.7
Volume reduction	97.4
Reduction of material driven off upon heating	99.2
Heat release from solid waste	99.0

SAFETY

The National Institute of Occupational Health and Safety surveyed the working conditions at the incinerator and it's report is contained in Appendix G.

General Observations

The appearance of both the facility and equipment in it is poor. Although efforts were made to keep the incinerator and grounds presentable, much more is required.

Disposal of residue and fly ash without cover exposes these materials to wind and rain water runoff and is unacceptable.

The fly ash spray water, flowing fly ash, and residue truck drainage that flow or are hosed into the ditch south of the incinerator should be diverted to the sanitary sewer to eliminate any possibility of polluting the Monatiquot River.

Maintenance programs are almost non-existent at the incinerator -- repairs are done as the equipment breaks. A preventative maintenance is required.

Although the particulate emissions were within the design of the facility, they were above the State's legal level of (0.1 gr/scf at 12% CO_2) as were the visible emissions (always below 20 percent opacity).

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APPENDIX A

EXAMPLE CALCULATIONS FOR RESULTS OF SOLID WASTE PROXIMATE ANALYSIS

Using the data (Table A-1) from the laboratory analysis of solid waste Sample SW-2, these example calculations show the methods used to calculate the moisture and ash contents, weight of material lost upon heating, and the gross calorific value of the total solid waste sample. The weight loss upon heating, the ash content, and the gross calorific value of the laboratory sample are determined on a dry basis. For these calculations, the noncombustibles were assumed to contain no gross calorific value and no material that could be driven off by heating. The field separation determined a combustible content of 86.6 percent and a noncombustible content of 13.4 percent (Text Table 5) on an as sampled basis.

TABLE A-1

LABORATORY DATA: SOLID WASTE PROXIMATE ANALYSIS

Sample number	Moisture (% as sampled)		Combustibles (Dry Basis)		
	Comb.	Noncomb.	Gross calorific value (Btu/lb)	Weight loss upon heating (%)	Ash (%)
SW-2	40.7	11.8	7403	89.8	10.2
SW-3	17.9	4.8	7983	87.0	13.0
SW-7	27.1	6.3	7443	85.0	15.0

Moisture Content. The moisture content of the total sample was calculated as follows:

$$\text{Percent moisture in total sample} = \left[\left(\frac{\text{lb moisture}}{\text{lb combustibles}}\right)\left(\frac{\text{lb combustibles}}{\text{lb waste}}\right) + \left(\frac{\text{lb moisture}}{\text{lb noncombustibles}}\right)\left(\frac{\text{lb noncombustibles}}{\text{lb waste}}\right)\right] \times 100.0$$

$$\text{Percent moisture in total sample} = \left[(0.407)(0.866) + (0.118)(0.134)\right] \quad 100.0$$

$$\text{Percent moisture in total sample} = 36.8$$

Weight Loss Upon Heating and Ash Content. Because the weight loss upon heating and the ash fractions are determined in the laboratory on a dry basis, the percent of combustibles (Text Table 5) must be converted to a dry basis by the following method:

$$\text{Percent dry component} = \frac{\text{weight of wet component minus the weight of water in the component}}{\text{dry weight of total sample}} \times 100.0$$

For example:

$$\text{Percent dry combustibles} = \frac{125.0 - 50.9}{91.0} \quad 100 = 81.4$$

These calculations are summarized in Table A-2.

TABLE A-2

CALCULATION OF PERCENT OF DRY COMPONENT: SOLID WASTE

SAMPLE SW-2

Component	Wet Weight (lb)	Moisture (%)	Moisture (lb)	Dry Weight (lb)	Percent by dry weight
Combustibles	125.0	40.7	50.9	74.1	81.4
Noncombustibles	19.0	11.8	2.1	16.9	18.6
Total Sample	144.0	36.8	53.0	91.0	100.0

The weight loss upon heating and the ash content of the total sample are calculated as follows:

$$\text{Percent material driven off upon heating in total sample} = \left(\frac{\text{lb material driven off upon heating}}{\text{lb dry combustibles}}\right) \times \left(\frac{\text{lb dry combustibles}}{\text{lb dry waste}}\right) \times 100.0$$

Percent material driven off upon heating in total sample SW-2 = (0.898)(0.814)100 = 73.1

Percent ash in total sample = 100.0 -(percent material driven off upon heating)

Percent ash in total sample SW-2 = 100.0 - 73.1 = 26.9

Gross Calorific Value. The laboratory determined the gross calorific value on a dry basis for the combustibles only. Therefore, the moisture content and the noncombustibles present in the total sample must be accounted for when calculating the gross calorific value of the total sample on an "as sampled" basis. The gross calorific value of the total sample is calculated as follows:

$$\text{Gross calorific value of total sample} = \frac{\text{Btu}}{\text{lb dry combustibles}} \times \left(1 \text{ minus } \frac{\text{\% moisture in total sample} + \text{\% dry noncombustibles in total sample}}{100}\right)$$

$$\text{Gross calorific value of total sample SW-2} = 7.403 \left(1 - \frac{36.8 + 11.7}{100}\right)$$

= 3,810 Btu per lb waste

APPENDIX B

EXAMPLE CALCULATIONS FOR RESULTS OF RESIDUE

PROXIMATE ANALYSIS

Using the laboratory data (Table B-1) from the proximate analysis of the combined fines and unburned-combustible fractions of the residue Sample R-1, these calculations show the methods used to calculate the ash content, the weight loss upon heating, and the gross calorific value of the total sample. The glass, rocks, and metals were assumed to contain no gross calorific value and were considered as "ash". The laboratory separation determined an unburned combustible and fines content of 17.6 percent (Text Table 8) on a dry basis.

Weight Loss Upon Heating and Ash Content. The percent of material driven off upon heating and ash was calculated as follows:

$$\text{Percent material driven off upon heating in total sample} = \left[\left(\frac{\text{lb material driven off upon heating}}{\text{lb dry unburned combustibles and fines}}\right)\left(\frac{\text{lb dry unburned combustibles and fines}}{\text{lb dry residue}}\right)\right] \times 100$$

$$\text{Percent material driven off upon heating in total sample R-1} = (0.049)(0.176) \times 100 = 0.9$$

$$\text{Percent ash in total sample} = 100 - \text{percent material driven off upon heating}$$

$$\text{Percent ash in total sample R-1} = 100.0 - 0.9 = 99.1$$

TABLE B-1

LABORATORY DATA: PROXIMATE ANALYSIS OF RESIDUE

UNBURNED COMBUSTIBLES AND FINES

Sample	Date	Weight loss upon heating (%)	Ash (%)	Gross calorific value (Btu/lb)
R-1	7/24	4.9	95.1	187
R-2	7/24	9.7	90.3	906
R-3	7/25	6.4	93.6	180
R-4	7/26	12.3	87.7	1227
R-5	7/26	5.3	94.7	767
R-6	7/27	4.4	95.6	610

Gross Calorific Value. The laboratory determined the gross calorific value on a dry basis for the fines and unburned combustibles portion of the residue samples. Therefore, the gross calorific value of the total sample on a dry basis is calculated as follows:

$$\text{Gross calorific value of total sample on a dry basis} = \left(\frac{\text{Btu}}{\text{lb dry unburned combustibles and fines}}\right)\left(\frac{\text{lb dry unburned combustibles and fines}}{\text{lb dry residue}}\right)$$

$$\text{Gross calorific value of total sample R-1} = (187)(0.176)$$

$$= 33 \frac{\text{Btu}}{\text{lb}}$$

APPENDIX C

EXCESS AIR AND CARBON DIOXIDE CALCULATIONS

From the solid waste ultimate analysis the amount of C, H_2, S, O_2, and N_2 are known. From these values the theoretical air for combustion and flue gases can be calculated. By measurement of incinerator outflows the amount of excess air can be determined and also the percent carbon dioxide in the stack gas.

The calculations for solid waste sample SW-1 and measurements for stack run C-1 are as follows:

1. Theoretical air for complete combustion:

Element lb/lb Solid Waste		lb Air/lb Element	lb Air/lb Solid Waste
C : 0.219		11.53	2.53
H_2: 0.033		34.34	1.13
S : 0.001		4.29	0.01
			3.67
Less O_2 in Fuel:	(0.203)	4.32	0.88
	Required (100 % total air)		2.79 lb air/ lb solid waste

and with (27,200 $\frac{\text{lb solid waste}}{\text{hr}}$) (2.79 $\frac{\text{lb air}}{\text{lb solid waste}}$)

you have 75,888 $\frac{\text{lb air}}{\text{hr}}$ required

2. Total mass into incinerator for complete combustion (100% air):

Total wet solid waste in	27,200 lb/hr
Theoretical air in	75,888
6% moisture in air	4,553
Total Mass Into Incinerator	107,641 lb/hr

3. Theoretical Flue Gases from Complete Combustion:

Product	Element lb / lb Solid Waste	lb Product / lb Element	lb Product / lb Solid Waste
CO_2	C: 0.219	3.66	0.8
H_2O	H_2: 0.033	8.94	0.3
SO_2	S : 0.001	2.0	0.002
N_2 from air used for CO_2	C : 0.219	8.66	1.9
N_2 from air used for H_2O	H_2: 0.033	26.41	0.87
N_2 from air used for SO_2	S : 0.001	3.29	0.003
N_2 from waste	0.4	1.0	0.4
			4.28
Less N_2 in air not used due to O_2 in fuel:	0.88	0.7685	0.68 lb flue gases / lb solid waste
			3.60

and therefore $(3.6 \frac{\text{lb flue gases}}{\text{lb solid waste}})(27{,}200 \frac{\text{lb solid waste}}{\text{hr}}) = 97{,}920 \frac{\text{lb}}{\text{hr}}$ flue gases

4. Total Mass Out of Incinerator Measured

Solid out (residue, grate siftings, fly ash, particulate, wastewater solids)	4,418 lb/hr
Flue gas out (38,156 cfm at STP w/M.W. = 29)	171,900 lb/hr
Measured Total Out:	176,318 lb/hr

5. Excess air must equal the difference between what was measured leaving the incinerator and what should have gone in for complete combustion with 100 percent total air. Thus, from (2) and (4)

$$\text{Total Excess Air (wet)} = \begin{array}{r} 176{,}318 \\ 107{,}641 \\ \hline 68{,}677 \end{array}$$

Stack gases were sampled and had 7 percent moisture by weight. Thus the excess dry air was (0.93)(68,677) = 63,870 lb/hr

which from (1) is: $\frac{63{,}870}{75{,}888}$ = 84% excess air

6. Carbon Dioxide Concentration

From (3) the rate of CO_2 produced is

$$\left(0.8 \ \frac{\text{lb } CO_2}{\text{lb solid waste}}\right)\left(27{,}200 \ \frac{\text{lb solid waste}}{\text{hr}}\right) = 21{,}760 \text{ lb/hr}$$

To convert this to a volume percent

$$\frac{CO_2 \text{ lb/hr}\left(\frac{1}{\text{M.W. } CO_2}\right)100}{\text{Flue gas lb/hr}\left(\frac{1}{\text{M.W. flue gas}}\right)} = \frac{(21{,}760)(29)(100)}{(171{,}900)(44)} = 8.3\%$$

APPENDIX D

PLANT EFFICIENCY CALCULATIONS

These calculations show the method used to calculate the percent weight and volume reduction, the material that can be driven off by heating, and the percent heat released. The following data were used and represent the average values during the test period.

TABLE D-1: EFFICIENCY CALCULATION DATA

Units	Solid Waste	Residue	Fly Ash	Wastewater Solids	Grate Siftings	Particulate
lb/hr (wet)	28,000	5200	-	-	-	-
Percent moisture	26.0	18.7	0.0	0.0	0.0	0.0
lb/hr (dry)	20,720	4230	120	16	19.4	35.5
Btu/lb	4,780	179	3410*	3410*	820	3410*
Percent Material drive off upon heating	73.7	1.9	23.6*	23.6*	8.5	23.6*
lb/cubic yard	238	1555	608	608*	N.M.	608*

*These values not measured but assumed to be the same as fly ash.

Weight Reduction. The total weight reduction of the plant on a dry basis can be calculated by dividing the total tons of dry effluents by the total tons of dry influents and substracting this value from one. The effluents include the residue, particulates, wastewater solids, and fly ash. The following formula is used:

$$\text{Percent weight reduction} = \left[1 - \left(\frac{\text{dry residue weight} + \text{dry particulate weight} + \text{dry wastewater solids weight} + \text{dry grate siftings wt}}{\text{dry weight of solid waste}} + \frac{\text{dry fly ash weight}}{\text{dry weight of solid waste}}\right)\right] \times 100$$

$$\text{Percent weight reduction} = \left[1 - \left(\frac{4230 + 35.5 + 16 + 19.4 + 120}{20720}\right)\right] \times 100$$

$$\text{Percent weight reduction} = \left[1 - \left(\frac{4422}{20720}\right)\right] \times 100$$

$$\text{Percent weight reduction} = \left[1 - 0.213\right] \times 100 = 78.7$$

Volume Reduction. The following formula was used to calculate the volume reduction:

$$\text{Percent volume reduction} = \left[1 - \frac{\left(\frac{\text{lb dry residue}}{\text{density of "as sampled" residue}}\right) + \left(\frac{\text{lb dry fly ash}}{\text{total lb of "as sampled" fly ash}}\right)}{\left(\frac{\text{lb "as received solid waste}}{\text{density of "as received" solid waste}}\right)} + \frac{\left(\frac{\text{lb particulate}}{\text{density of particulates}}\right) + \left(\frac{\text{lb wastewater solid}}{\text{density of wastewater solids}}\right) + \left(\frac{\text{lb grate siftings}}{\text{density of grate siftings}}\right)}{\left(\frac{\text{lb of "as received" solid waste}}{\text{density of "as received" solid waste}}\right)}\right] \times 100$$

For the study period, the following volume reduction was achieved:

$$\text{Percent volume reduction} = \left[1 - \left(\frac{\frac{4230}{1555} + \frac{120}{608} + \frac{35.5}{608} + \frac{16}{608} + \frac{9.7}{\text{n.m.}}}{\frac{28{,}000}{238}}\right)\right] \times 100$$

$$\left[1 - \left(\frac{2.72 + 0.20 + 0.06 + 0.03}{117.65}\right)\right] \times 100$$

$$\left[1 - 0.026\right] \times 100 = 97.4$$

n.m. = not measured

Reduction in Material that Can be Driven Off Upon Heating. The following formula was used to calculate the weight reduction of material that can be driven off upon heating (WLUH):

Percent reduction in material that can be driven off upon heating =

$$\left[1 - \left(\frac{\text{wt. residue x residue WLUH + wt. fly ash X fly ash WLUH}}{\text{wt. solid waste X solid waste WLUH}} + \right.\right.$$

$$\frac{\text{wt. particulate X particulate WLUH + wt. of grate siftings X grate siftings WLUH}}{\text{wt. solid waste X solid waste WLUH}} +$$

$$\left.\left.\frac{\text{wt. of wastewater solids X wastewater solids WLUH}}{\text{wt. solid waste X solid waste WLUH}}\right)\right] \times 100$$

Percent reduction in material that can be driven off upon heating =

$$\left[1 - \frac{4230 \times 0.019 + 120 \times 0.236 + 19.4 \times 0.236 + 35.5 \times 0.236}{(20720) \qquad (0.737)}\right] \times 100$$

$$\left[1 - \frac{80.37 + 28.32 + 8.38 + 3.78 + 4.6}{15{,}271}\right] \times 100$$

Percent reduction in material that can be driven off upon heating $= \left[1 - \frac{125}{15271} \quad 100\right] = \left[1 - 0.008\right] \times 100 = 99.2$

Heat released. The percent available heat released is calculated using the formula:

$$\text{Percent of available heat released} = \left[1 - \left(\frac{\text{Btu/lb residue} \times \text{lb residue}}{\text{Btu/lb solid waste} \times \text{lb solid waste}} + \frac{\text{Btu/lb fly ash} \times \text{lb fly ash} + \text{Btu/lb particulate} \times \text{lb. particulate}}{\text{Btu/lb solid waste} \times \text{lb solid waste}} + \frac{\text{Btu/lb wastewater solids} \times \text{lb wastewater solids} \times \text{Btu/grate siftings} \times \text{lb. grate siftings}}{\text{Btu/lb solid waste} \times \text{lb solid waste}}\right)\right]$$

$$\left[1 - \frac{179 \times 4230 + 3415 \times 120 + 3415 \times 35.5 + 3415 \times 16 + 820 \times 19.4}{4780 \times 28{,}000}\right] \times 100$$

$$\left[1 - \frac{757{,}200 \quad 409{,}800 + 121{,}200 + 54{,}600 + 16{,}000}{133{,}840{,}000}\right] \times 100$$

$$\left[1 - \frac{1{,}360{,}500}{133{,}840{,}000}\right] \times 100 = \left(1 - 0.010\right) \times 100 = 99.0$$

APPENDIX E

BOILER EFFICIENCY CALCULATION

The boiler efficiency is defined as the ratio of heat used to make steam to the heat available from the solid waste. The steam system is a closed loop system with approximately 5% makeup. It is assumed that the deaerator supplies the boilers with 240 F saturated liquid and the boilers produce 52,106 lb/hr of saturated vapor at 194.39 psig.

Therefore:

$$\text{Boiler efficiency} = \left[\frac{\text{Heat to make steam from deaerator water} + \text{Heat to bring makeup water from tap to deaerator conditions}}{\text{Heat available from solid waste}}\right] \times 100$$

$$= \left[\frac{(52,106)(1198.89 - 208.34) + (52,106)(0.05)(208.34 - 38.04)}{(28,000)(4780)}\right] \times 100$$

$$= \frac{51,613,600 + 443,600}{133,840,000} \times 100 = 39\%$$

APPENDIX F

HEAT BALANCE CALCULATIONS

Of the total heat into the incinerator from the solid waste it was calculated in Appendix D that 99.0 percent of it was released. This heat was then taken away by:

1. sensible heat in stack gases, wastewater, and solids discharged
2. steam production
3. solid waste moisture vaporization
4. radiation losses

Using average values and making some simplifying assumptions the heat losses can be calculated as follows:

1. Sensible heat ($q=mC\ T$)

   a. Stack gases (assume same specific heat and density as air):

$$q\left(\frac{Btu}{hr}\right) = 37{,}700\ \frac{cuft}{min} \times 60\ \frac{min}{hr} \times 0.075\ \frac{lb}{cuft} \times 0.245\ \frac{Btu}{lb\ F} \times (494-70)$$

$$= 17{,}620{,}000\ Btu/hr$$

   b. Wastewater:

$$q\left(\frac{Btu}{hr}\right) = 84\ \frac{gal}{min} \times 60\ \frac{min}{hr} \times 0.1337\ \frac{cuft}{gal} \times 62.4\ \frac{lb}{cuft} \times 1\ \frac{Btu}{lb\ F}$$

$$\times (115-70)F$$

$$= 1{,}890{,}000\ Btu/hr$$

c. Solids (assume specific heat of all solids is 0.15 Btu/lb F and that they leave the facility at 115 F):

$$q\left(\frac{Btu}{hr}\right) = 4420 \frac{lb}{hr} \times 0.15 \frac{Btu}{lb\ F} \times (115 - 70)\ F$$

$$= 30{,}000\ Btu/hr$$

2. Steam production

From Appendix E; $q\left(\frac{Btu}{hr}\right) = 52{,}060{,}000.$

3. Solid waste moisture vaporization

$$q\left(\frac{Btu}{hr}\right) = 28{,}000 \frac{lb}{hr} \times 0.26 \frac{lb\ H_2O}{lb} (1287.1 - 38.04) \frac{Btu}{lb\ H_2O}$$

$$= 9{,}090{,}000\ Btu/hr.$$

4. Vaporization of water formed from combustion

$$q\left(\frac{Btu}{hr}\right) = 28{,}000 \frac{lb}{hr} \times 0.037 \frac{lb\ H_2}{lb} \times 9 \frac{lb\ H_2O}{lb\ H_2} \times (1287.1-38.04) \frac{Btu}{lb\ H_2O}$$

$$= 11{,}646{,}235 \frac{Btu}{hr}$$

5. Radiation losses

Assume total losses of 10% of heat released:

$$q\left(\frac{Btu}{hr}\right) = 0.10 \times 0.99 \times 133{,}840{,}000$$

$$= 13{,}250{,}000.$$

Thus the total calculated heat loss is the sum of 1-5 or:

$$q\ (Loss\ Total) = 105{,}586{,}235$$

The total heat released:

$$q\ (Released) = 0.99 \times 133{,}840{,}000$$

$$= 132{,}500{,}000.$$

APPENDIX G

Health and Safety Report

for the

Braintree, Massachusetts Incinerator

Introduction

The following report is based on a survey of the Braintree incinerator on July 25-26, 1972 by Messrs. Paul Caplan, James Walters, and Gerald Karches. We were requested by the Bureau of Solid Waste Management, Environmental Protection Agency, to inspect this particular plant from the health and safety aspects of the employees. This is the first in a series of inspections of various types and sizes of incinerators with the eventual goal being to write a chapter for a manual on incinerator operations. The intent of this paper is to report those problem areas observed and to recommend general principles of control. Safety considerations will be presented first and then the health aspects.

The Braintree facility is rather new (1970). According to the plant manager, it is one of three such incinerators in this country. The facility's 13 employees are members of the AFL/CIO. The Braintree incinerator is owned and operated by a municipal government; therefore, it does not come under the umbrella of the Federal Occupational Safety and Health Act. Regular inspections, however, are made by State occupational health and safety representatives. One unique feature of this operation is that in the incineration of trash and garbage, steam is produced and sold to nearby industries. The rated capacity of this facility is five tons/hour for each of the two incinerators and is operated continuously which makes the total capacity

240 tons of garbage and trash per day. This unit is a bridging arc, back firing incinerator which operates at a temperature of between 1500-2000°F.

SAFETY CONSIDERATIONS

General Findings

Presently, there is no formalized safety program at the Braintree facility. However, discussions with employees indicated that the formation of a safety committee had been suggested to management by their union representative, and that such a committee might become a reality within a few weeks. This was confirmed by the plant manager who also felt that a formalized training and orientation program for new employees should be developed. Presently, neither exist and there is no time table for implementing such a program. Overall, the employees and the plant manager had a good understanding of safe practices and procedures. Both expressed an awareness of many of the problems relating to safety around the facility but there was little evidence that any action had been taken to minimize the possibility of sustaining an injury.

Recommendations

1. Organize a safety committee composed of both workers and management for purposes of determining safe practices, procedures, maintenance programs, etc.

2. Establish a formalized orientation program for all employees and provide special training for those working in or around high risk areas.

3. While safety is the responsibility of everyone, it is felt that it should be the responsibility of management to get an effective safety program underway at this facility.

Specific

First Aid

The first-aid kit on display inside the incinerator control room consists of a few rolls of gauze plus an antibiotic and is therefore considered inadequate. Conversation with both workers and plant managers revealed that no one on the premises is trained in first aid. Only two employees have had some previous training--both 8-10 years ago.

Recommendations:

1. Immediately enroll one or more employees in an advanced first-aid course, preferably one offered or sanctioned by the American Red Cross.

2. Replenish the first-aid kit and consider purchase and display of additional ones on floors other than the incinerator control room.

3. Indicate in a conspicuous manner the location of first-aid kits or stations.

Emergency Considerations

There has been little planning for handling emergencies at the Braintree facility. The procedures that have been instituted for handling emergencies are at best questionable, i.e., a person falling into the 30-foot deep refuse pit must rely upon the availability of fire department personnel to rescue him.

Recommendations:

1. Emergency lighting has been installed in the incinerator control room. Similar lighting should be installed in the top three floors, particularly the precipitator floor. In the event of power failure, evacuation or rescue operations would be hampered without adequate lighting.

2. There is no communication system between floors. Since noise and distance prohibit verbal communications, some type of signal or alert system should be extended to all floors to handle emergency situations.

3. Removing an injured victim from the top floors of the building through a series of stairwells would be most difficult. A stretcher located near the top floors would serve as a valuable aid in removing an injured victim.

4. Exits and danger areas are unmarked. Both should be appropriately identified.

5. Emergency phone numbers were not posted or known by any of the employees. Such numbers should be identified and placed near the phone.

Fire Prevention

Presently, there is no established fire escape plan or fire alert system. Fire extinguishers are adequate in terms of types and numbers. However, there is no designation as to where they are located, or any indication to show date of last charging and inspection. With one or perhaps two exceptions, all extinguishers were improperly mounted. Unusual amounts of flammable materials (paper boxes, mops, containers, etc.) were observed in the hallway which also serves as an escape way. Cylinder tanks were improperly secured and unlabeled.

Recommendations:

1. An unmistakable evacuation alarm system, used for no other purpose, should be installed and identified as such.

2. Fire evacuation drills should be conducted.

3. Storage of combustible materials in hallways should be discontinued.

4. Exits should be clearly marked with six-inch letters and suitably lighted.

5. Annual inspections should be considered maximum elapse time for inspection of fire extinguishers. A much shorter interval between inspections would be desirable.

6. Extinguishers should be properly mounted in conformance with recommended State or Federal fire codes.

7. Cylinder and similar pressurized tanks should be labeled as to their contents, secured firmly in an upright position, away from flame or heat sources.

LIGHTING

The plant was visited at 9:00 p.m. to determine the adequacy of lighting. Measurements were taken throughout the plant and outside where work is performed or readings are taken. Light levels could not be satisfactorily read less than one foot candle. The following table lists the light levels obtained at the various locations.

Table I

Light Levels by Plant Location

Light Levels Ft. Candles	Location	Recommended Lighting Levels Ft. Candles
22	Control Panel	30
4	First Floor	20
8	Pumps on First Floor	20
5	Steps on First Floor	20
17	Loading Area	20
5	Dumpster Area	20
<1	Dump Area	0.1
<1	Outside Meter Reading Station	2
150	Condenser (85 ft. level)	10
<1	Roof (precipitator)	5

Recommendations:

1. All lighting levels in the work areas should be 20 foot-candles.

2. All outside lighting should be upgraded.

3. The precipitator on the roof should have at least 2 foot-candles of lighting installed as soon as possible.

Working Areas

Crane Operation Room

The crane used to transfer rubbish from the dumping pit to the incinerator is located on the fourth floor and presents certain hazards requiring attention. The crane is not equipped with a signaling device to indicate sudden lateral movement, a hazard to other employees and bystanders. Noise in this area makes verbal communication almost impossible. One of the more serious potential hazards is the danger from flash back of fire, smoke, and heated air from the incinerator pit toward the crane operator. Flash occurs under certain burning conditions (dry, moist, damp, etc.). Evidence of such flash backs was observed around the crane operating area. Considering that the operator is inside the enclosed cab of the crane during a flashback, it is unlikely that he would be injured; however, should he or other employees be engaged in routine chores outside the cab of the crane, a real hazard exists. This potential hazard is increased since there is only one exit from the crane floor area.

Recommendations:

1. Crane should be equipped with a signaling device to alert other employees or bystanders of lateral movement.

2. Consideration should be given to constructing a barrier or similar protective device that would afford protection from flashback to anyone happening to be in the crane area.

3. A second exit and emergency procedures should be devised for rescuing the crane operator in the event of fire on lower floors.

Precipitator Area

Two precipitators are located on the top floor of the incinerator building, approximately 85 feet from ground level. One employee was injured as a result of a fall from the ladder just prior to our inspection. Portable ladders are used to climb from the precipitator floor to reach controls located on top of the precipitator. There is no communication system from this floor nor an outside exit.

Recommendations:

1. The fixed ladder should be replaced with stairs and railings consistent with the type in use on other floors.

2. Catwalks or platforms around the precipitator should replace the portable ladder presently used to check meters or reach controls on top of the incinerator.

3. A communication system should be set up between the precipitator area and lower floors, and procedures for handling emergencies in this area should be developed and practiced.

4. Consideration should be given to the installation of an outside exit.

Residue Conveyor Pit

The residue conveyor pit is located directly below the two incinerators. Residue represents the remains of materials which the incinerators are unable to burn. Residue is dropped from the grates inside the boiler into a channel of water where it is cooled. A conveyor belt running through the channel of water then carries the residue to an outside area where it is loaded onto a truck and disposed of in a nearby land fill. The conveyor

belt moves rather slowly. As the residue cools, the water becomes very hot (180° when both incinerators are operating) and in areas where the conveyor pit is unguarded a serious hazard exists. The water in the conveyor pit, in addition to being very hot, is deep--according to employees from four to six feet. Two persons, one employee and one visitor, have fallen into the pit. In both instances, only one boiler was in operation, therefore decreasing the temperature of the water. Fortunately, both escaped serious injury. Three unguarded areas were observed during the inspection, two inside the plant facility and one in the outside loading area. The outside area was protected by a fence and an unlocked gate. Dimensions of openings were 50" X 30", 50" X 62", and 50" X 42".

Recommendation:

All openings along the conveyor channel should be covered, properly guarded, and appropriate warning notices posted.

Refuse Dumping Pit

The refuse dump pit is approximately 50 feet wide, 40 feet long, and when empty about 45 feet deep. A 14" high beam is installed along the front perimeter of the pit to prevent vehicles from backing into the pit area. A warning sign urging parents to keep children inside their vehicles while unloading refuse is posted near the pit site. According to employees and the plant manager, the sign does little to discourage adults from allowing children to wander and play around the pit. During the inspection, a number of children ranging in ages from approximately 5-14 were observed throwing refuse over the perimeter of the pit. For various reasons, no

real effort is made on the part of the plant manager to enforce the warning. Under certain weather conditions, snow, ice, high winds, etc., the dumping pit becomes a real danger area. Should either an employee or member of the general public accidentally fall into the open pit, rescue efforts would be drastically hampered. There are no fixed ladders, entrances, or exits from which the pit can be entered or vacated. Presently, the only manner in which a victim can be rescued from the pit is by calling the local fire department. They feel that the fire department could respond rather quickly with the necessary rescue equipment.

Recommendations:

1. One can only speculate about the inevitable liability suit as a result of a child or adult being injured from falling into the unguarded pit. The installation of appropriate railings and the enactment and enforcement of dumping procedures would minimize this potential hazard.

2. A fixed ladder should be installed or some other means of entrance or exit provided for rescue purposes. Reliance on the fire department to respond in such an emergency is at best very risky.

3. Appropriate footwear should be provided for employees working around the refuse area during adverse weather conditions.

Metal Scrap Area

Dust, flying chips, loose wires, protruding objects, glass, etc., are obvious hazards in this area. At the time of inspection, only one of five employees was wearing safety shoes and one other was wearing an aspirator. According to employees, gloves, safety glasses, hats, goggles, and respirators are available if they choose to use them. Safety shoes were the exception.

Employees are allowed $6.00 every six months toward the purchase of safety shoes; however, most of them indicated that they did not take advantage of this allowance.

Recommendations:

1. All employees should be provided with and required to wear appropriate safety equipment while working in the scrap metal area.

2. Appropriate signs and warnings should be posted indicating that personal safety equipment must be worn by both employees and visitors while in this area.

Residue Dumping Area

Residue representing unburned materials from the incinerator, after being cooled by exposing it to water, is loaded by conveyor onto a large truck and transported to a land fill area near the incinerator site. Considerable dumping takes place at night in an unlighted area made more hazardous by a number of deep "drop-offs" where the truck must back to unload. The truck is not equipped with back-up lights and therefore requires that the driver periodically leave the truck and view the location of the truck in reference to the "drop-offs." The driver uses a flashlight or matches as light sources. The truck is not equipped with a fire extinguisher.

Recommendations:

1. Additional lighting should immediately be installed in the residue dumping area.

2. The dump truck should be provided with back-up lights and a fire extinguisher placed inside the cab.

3. The driver should be supplied with and required to wear appropriate personal safety equipment.

HEALTH CONSIDERATIONS

Noise level measurements were taken at various locations in the plant. The highest level recorded was 88 dB(A) at the generator and pump area on the ground floor. This is below the 90 dB(A) noise standard of OSHA for continuous daily exposure and therefore no noise violation was observed.

Table II

Noise Level Around Incinerator Site

Location and Operation	Noise Level dB(C)	Noise Level dB(A)	Remarks
Control panel, operator	84	79	Normal operation
Water tank level area	84	81	No one working at time
Electrostatic precipitator area	84	80	No one in area
Generator and pump area	92	88	Normal working area

ENVIRONMENTAL EXPOSURES TO DUST

Rafter samples were collected in area of the crane and in the work areas of the building near incinerators. These were analyzed for crystalline free silica (quartz) content, in order to determine their potential inhalation hazard. Silica contact ranged from 6.50% to 9.35% with an average of 7.7%. On the basis of their silica content, the threshold limit value for an average eight hour day exposure would be approximately three milligrams per cubic meter of air (mg/M^3*).

In our opinion, dust concentrations at the working locations were well below their recommended standard and constitutes no dust inhalation hazard.

Environmental Heat Exposures

Exposures to hot environmental conditions were measured at approximately 1:00 p.m. to estimate the degree of heat stress encountered during normal work operations. Conditions inside the plant were compared with outdoor conditions, which indicate that plant operations provide an additional heat burden in excess of outdoor conditions.

Standard for Work in Hot Environments

NIOSH has recently published a "Criteria for a Recommended Standard for Occupational Exposure to Hot Environments".[1] According to this standard, a "hot environmental condition" means any combination of air temperature, humidity, radiation, and wind speed that exceeds a Wet Bulb Globe Temperature (WBGT) of 79°F.

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*Based on TLV for Chemical Substances of the American Conference of Governmental Industrial Hygienists 1972 formula: $TLV = \frac{30\ mg/M^3}{\text{\& quarterly} + 3}$

WBGT for indoor exposures or outdoor exposures with no solar loads is calculated by the following formula: WBGT ^{o}F = 0.7 WBT + 0.3 GT (or DBT)

WBT = natural wet bulb temp. - ^{o}F

GT = globe thermometer temp. - ^{o}F (with no radiant heat load. Globe temperature is equal to dry bulb temperature - DBT)

The Standard also recommends the following work practices (in summary) to be followed by personnel exposed to a "hot environmental condition."

(a) For sedintary work where continuous unimpaired mental performance is required (e.g. control operator), no employee shall be exposed to conditions which exceed the limits set forth in Figure I-1.

(b) No employee should be permitted to work without "protective observation" at high heat stress levels.

(c) When exposure of an employee is continuous for one hour or intermittant for a period of two hours and the average WBGT exceeds 79^{o}F for men or 76^{o}F for women, one or several practices shall be initiated to insure that employees' body care temperature does not exceed 100.4^{o}F. (These are discussed later in Recommendations.)

Effects of Heat

The three major clinical disorders resulting from heat stress on susceptible workers are: (1) heat stroke from failure of the thermo regulatory center; (2) heat exhaustion from depletion of body water and/or salt; and (3) heat cramps from salt loss and dilution of tissue fluid.

Other clinical entities from heat effects are heat syncope (fainting), heat rash, and types of heat fatigue. For a full discussion of these

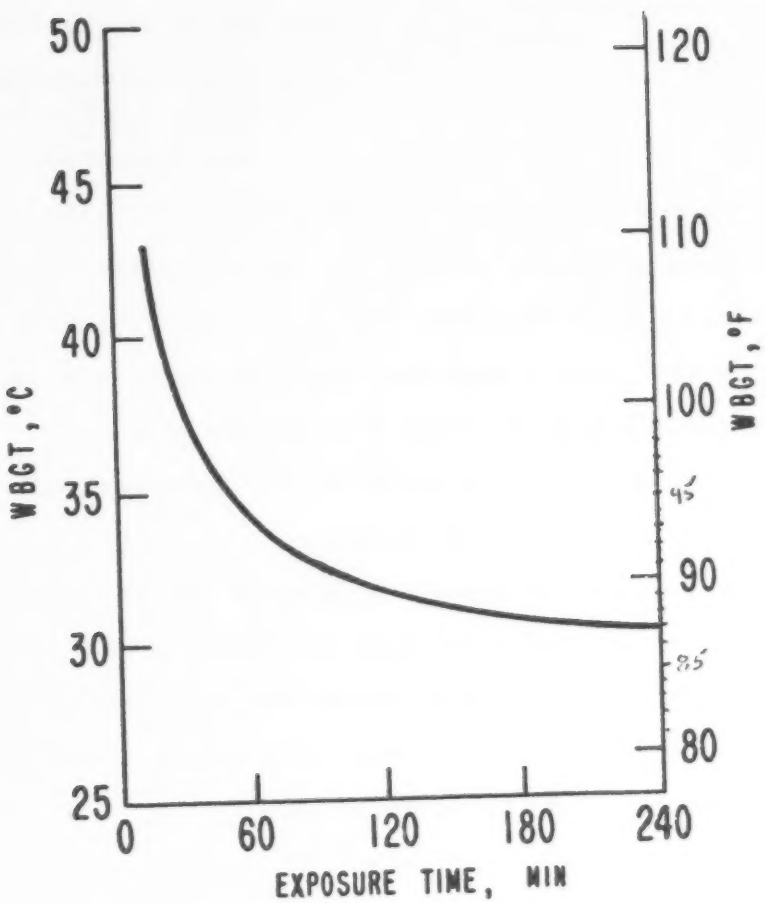

FIGURE I-1. UPPER LIMITS OF EXPOSURE FOR UNIMPAIRED MENTAL PERFORMANCE

Reference: Criteria for a Recommended Standard Occupational Exposure to Hot Environments, NIOSH, U.S.D.H.E.W., HSM 72-10269, 1972.

medical symptoms, we refer you to the NIOSH Recommended Standards on Occupational Exposure to Hot Environments.

Environmental Heat Measurements

Psychrometric measurements plus calculated Wet Bulb Globe Temperatures and maximum exposure times for unimpaired mental performance are shown in Table I.

Table I

Environmental Heat Exposures

Wet Bulb Globe Temperatures (WBGT)

Location	WBT °F	GT or DBT°F	WBGT °F	Max. Continuous Exposure--Minutes
Outside bldg. (shade)	79	85	80.9	-
Rest Room				
a)	81	87	82.8	-
b)	81	84	81.9	-
c)	81	84	81.9	-
Central Panel Operator				
a)	82	88	83.8	-
b)	83	90	85.2	-
Precipitator Meter, 2 flights above central panel	88	104	92.8	80
a)	88	104	92.8	80
b)	88	100	91.6	100
c)	89	99	92.0	80
Top of Incinerator	94	107	97.9	40
Heat Exchanger	93	105	96.7	50
1 Flight above central panel	91	99	93.4	60
a)	90	97	92.1	70
Above Economizer	82	87	83.5	-
Limit for Men			79°	

All measurements of heat stress on July 25, 1972 indicated indoor work conditions to be hotter than ambient outdoor conditions (Table 1, Location 1). Furthermore, on this day all WBGT readings--indoor, outdoor, including the rest room area--exceeded the lower limit of a hot environmental condition (79°F WBGT). Therefore, we conclude that whenever outdoor ambient heat conditions exceed the lower limit for hot environments, inside work conditions will also exceed the limit and require "protective observation" to prevent or treat one or more of the major clinical disorders resulting from excessive heat stress.

Recommendations

Whenever environmental heat conditions (above 79°F WBGT) exist at employee work sites, the following work practices and heat strain preventive measures should be instituted:

1. Conduct a temperature profile for each work place to serve as a guide for work practices, particularly during the summer months of July and August.

2. Acclimatization--normal acclimatization to heat stress conditions requires approximately six days. Unacclimatized employees should be acclimatized over a period of six days, by restricting work load to 50% of normal on the final day; followed by daily 10% increments, building up to 100% of total exposure on the sixth day.

3. A work and rest regimen should be implemented to reduce peaks of psychological strain and improve recovery during rest periods. Regular work breaks should be provided at a minimum of one every hour to get water and replacement salt. Employees should drink at least eight quarts of cool,

potable water, salted (50-60°F with about .1% salt) per shift, preferably in multiple small amounts. The water supplies should be located as near as possible to the positions where employees are regularly working, but never further than 200 feet away. It is important to realize that probably workers will not voluntarily drink enough water to replace water and salt losses. Therefore, instruction on the need for drinking water regularly must be given.

4. Wherever environmental conditions exceed 86°F WBGT, place warning signs to show: WARNING--Heat Stress Area.

5. First-Aid Training--Employees who may be exposed to environmental heat stress should be given training in health and safety first aid procedures including the following: value of water and salt intake for replacement procedures; importance of weighing each day, before and after work; instruction on how to recognize the causes and symptoms of heat disorders and illness, including dehydration, stroke, exhaustion, cramps, syncope (fainting), rash, and fatigue.

* U.S. GOVERNMENT PRINTING OFFICE: 1973 - 759-918/3133, REGION No. 5 - 11

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